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# DOMESTIC SCIENCE

## PART II

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# DOMESTIC SCIENCE

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## PART II

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# PREFACE

IN this volume the matters dealt with in Part I receive amplification and their application to domestic affairs is considered more fully. In addition a considerable amount of new matter is included, which will be found in the later chapters of the book.

The complete work is intended to provide the groundwork in science necessary for all students under instruction in domestic crafts and no attempt has been made to render it encyclopaedic in character.

The author's thanks are tendered for the loan of illustrations to Messrs Macmillan and Co. (Fig. 2); The Coalbrookdale Co. (Fig. 23); The Interoven Stove Co. (Figs. 25 and 26); The Welsbach-Kern Co. (Fig. 27); Messrs R. and A. Main (Fig. 29); Simplex Conduits, Ltd. (Fig. 30); Messrs Spiers and Pond (Fig. 31); Messrs Condrup (Figs. 37 and 38); Messrs J. J. Griffin (Fig. 40); Messrs Whittaker and Co. (Fig. 44); General Electric Co. (Fig. 45); The Berkefeld Filter Co. (Fig. 46); Messrs Chapman and Hall (Figs. 55 to 58) and Messrs Swan Sonnenschein and Co. (Fig. 79).

CHARLES W. HALE.

CHELSEA,
*May*, 1916.

NOTE.—The London County Council accepts no responsibility for the author's opinions and conclusions.

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# ERRATA

p. 222, l. 11. *For* Protein *read* Proteid

p. 284, Question 2. *For* disadvantages of a stove compared *read* disadvantages of such a stove as compared

p. 297. *For* Pietrowski *read* Piotrowski

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# CHAPTER I

## FUELS; COMBUSTION; FLAME

1. Under the heading of fuels are grouped many substances differing widely in appearance and in properties. Chief among them may be mentioned wood, peat, soft coal, coke, anthracite, coal-gas, paraffin oil, and alcohol. Chemical examination of these substances reveals that they are all composed of the elements carbon and hydrogen, united in various proportions, together with smaller amounts of other elements, of which oxygen and nitrogen are most important. The average percentage composition of some common fuels as given below illustrates this similarity in composition.

| | Percentage of | | | | |
|---|---|---|---|---|---|
| | C | H | O | N | Ash |
| Wood .. .. | 45 | 6 | 48 | 1 | 1·5 |
| Peat .. .. | 60 | 6 | 32 | 2 | 5–20 |
| House coal .. | 82 | 5 | 12 | 1 | 1–15 |
| Anthracite .. | 94 | 3 | 3 | — | 1·5 |
| Charcoal .. | 95 | 1·6 | 3·4 | — | 4 |
| Coke .. .. | 96 | 0·5 | 2·5 | 1 | 3–11 |
| Coal-gas .. | 32 | 60 | 5 | 3 | — |
| Paraffin oil .. | 85 | 15 | — | — | — |
| Alcohol .. | 52 | 35 | 13 | — | — |

The percentages of carbon, hydrogen, oxygen, and nitrogen given are calculated after deducting the amounts of ash (incombustible matter) and water present in all the solid fuels mentioned. The increase in the proportion of carbon and the corresponding decrease in that of oxygen, consequent on the gradual transformation of wood into anthracite by way of peat and soft coal, should be noted.

2. The change of vegetable matter into an almost pure form of carbon, such as anthracite, is only effected by natural agencies during the course of very long periods of time. Water and compounds of carbon and hydrogen are eliminated during the process. A similar transformation may be brought about in the laboratory, and also upon the large scale, by causing the vegetable matter to decompose more rapidly under the influence of a high temperature in the absence of air.

EXPERIMENT 1. Place a small piece of wood, previously weighed, at the bottom of a small crucible and cover it with a layer of white sand. The sand should have been heated to a red heat before use and stored, after cooling, in a dry bottle. Place the crucible upon a pipeclay triangle, and support the latter upon a tripod stand. Heat the crucible to bright redness with a powerful Bunsen flame for about 15 minutes. Allow the apparatus to cool and then remove the layer of sand. A fragment of charcoal will be found at the bottom of the vessel. This retains the shape of the original piece of wood to some extent, but is black and, on weighing, will be found to weigh about one-quarter as much as the wood. Preserve the charcoal for use in a later experiment.

3. A similar method of preparation of charcoal is in general use on the large scale, but the products of the decomposition have now so great a commercial value that they are usually not permitted to escape, as in the experiment just done, but are collected with great care. An approximation to the method employed is described in the next experiment.

EXPERIMENT 2. Half fill a tube made of hard glass with small pieces of wood. Support the tube upon a Bunsen burner, as shown in Fig. 1. Fit up the remainder of the apparatus shown, the wash-bottle being partly filled with water. Heat the tube, gently at first to minimise the risk of cracking it, and then gradually raise the temperature until the full power of the burner is in use. Reject the first few bubbles of gas which escape through the water in the trough, as these consist almost entirely of air expelled from the apparatus by the gases derived from the decomposition of the wood. Collect the remainder of the gaseous product in jars over water. Note the production of a watery distillate which trickles down the delivery tube into the water in the wash-bottle, followed later by a much thicker tarry substance. When no more gas is evolved, stop the heating, disconnect the hard glass tube from the wash-bottle, and allow the apparatus to cool down. Remove the jar of gas first collected from the trough, and shake up the contents of the jar with a little lime-water. The formation of a slight turbidity indicates the presence of a small quantity of carbon dioxide, produced by the burning of a little of the wood. Light the gas in a second jar, and, after its combustion is completed, shake up with lime-water. The turbidity in this case will be much more pronounced, showing that the wood-gas contains compounds of carbon, which are inflammable and produce carbon dioxide on combustion. If the appearance of the inside of the jar be carefully watched during the burning of the gas, a deposition of moisture will be noted, indicating the presence in the wood-gas of hydrogen or of inflammable compounds of hydrogen, which form steam when burnt. A better test for the presence of the hydrogen is afforded, should sufficient gas be evolved, by burning a jar of dry gas. Pass the end of the delivery tube, fixed in the cork of the combustion tube, to the bottom of a clean dry jar held in an inverted position. Allow the gas to pass into the jar for two minutes and then remove it, and burn the gas with the jar still held upside down. The formation of a deposit of moisture upon the interior of the jar is a certain sign that hydrogen is present in the wood-gas. Shake out the contents of the tube, when cold, and examine the appearance of the charcoal obtained by this method, comparing it with that previously obtained.

The process just described, wherein a substance is resolved into simpler substances, of which some are separable on account of their greater volatility from the less readily volatile products, is known as "dry" or "destructive" distillation. Where wood is plentiful, the operation is carried out on the large scale in iron retorts, and the watery portion of the distillate is further treated in order to obtain from it several substances of commercial value, of which methyl alcohol (wood-spirit) and acetic acid (white vinegar) are of prime importance. The gas is sometimes used for lighting purposes and the tarry matter, especially that obtained from pinewood, is used as a preservative for wood under the name of Stockholm tar.

4. Coal is treated in similar fashion in vast quantities in the process of manufacturing coal-gas.

Experiment 3. Fit up the apparatus shown in Fig. 1. The hard glass tube is half filled with small pieces of ordinary house coal. This is heated and the products of its decomposition observed and treated as previously described for wood in Experiment 2. On breaking the hard glass tube when cold, a more or less compact porous mass—coke—is obtained.

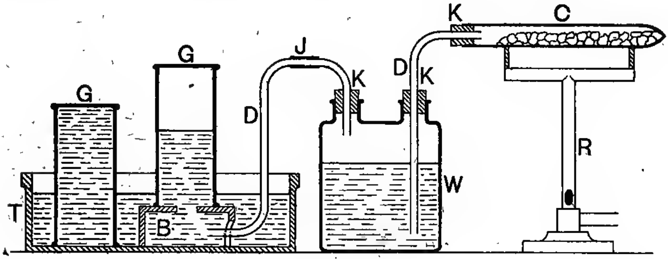

Fig. 1.

*R* = Bunsen burner fitted with tube support.
*K* = tight-fitting cork.
*J* = rubber joint.
*G* = gas-jar.

*B* = stoneware beehive cell.
*C* = hard glass tube.
*D* = glass delivery tube.
*W* = Woulfe's bottle.
*T* = stoneware trough.

The lighter watery fraction of the distillate from coal is the chief source of ammonia (spirit of hartshorn) and its compounds, such as ammonium chloride (sal ammoniac) and ammonium carbonate (washing ammonia). Test the gas in one of the jars and also the water in the wash-bottle at the end of the experiment with red litmus paper. The presence of an alkaline substance will be shown by the colour changing to blue.

From the tarry portion of the distillate are obtained most of the colouring matters in use at the present day. A part of the tar is still used as a preservative and also as a binding material for paths and roadways. Many disinfectants of great value are also prepared from the residues of coal-tar, which was formerly considered as a waste product of little commercial value.

Repeat the above experiment, using small pieces of anthracite instead of house coal. Compare the quantity of gas collected in this case with that previously obtained and note also the relative amounts of tarry matters produced. It will be found that, even when the heating of the anthracite with the most powerful flame producible with the burner used is prolonged, very little gas and tar will be obtained. Reference to the table in par. 1 will help to explain this. The coal used in ordinary households is of a bituminous (tar-producing) character and contains a higher proportion of hydrogen and oxygen than anthracite. When subjected to dry distillation, therefore, more liquid and gaseous products—chiefly compounds of carbon with hydrogen or oxygen—are formed from ordinary coal than from anthracite. The almost total absence of nitrogen in the latter precludes the possible formation of ammonia—a compound of nitrogen and hydrogen—during the heating process.

5. The manufacture of coal-gas may well be more fully dealt with as an example of the processes involved in modern methods for the preparation of substances in common use. Fig. 2 represents in a diagrammatic

form a coal-gas works. From five to nine fireclay retorts, of ⌓-shaped section, are placed in tiers in the same furnace, which is commonly of the "producer-gas" type in which the retorts are heated by the flames of burning gas, produced by passing alternate currents of air and steam through burning coke or small coal. The lower retort in the figure is shown in longitudinal section. From the outer end of each retort—the charge of which is about 2 cwt. of coal—rises the *ascension-pipe*, which carries the gaseous products of the distillation to a large pipe—the *hydraulic main*—half filled with condensed coal-tar and water from previous operations. The end of the ascension-pipe dips beneath the liquid surface, and the gaseous mixture is partially cooled and condensed by this means. The excess of liquid matter in the hydraulic main produced by this partial condensation overflows into a pipe leading to the tar-well. The more volatile portion of the distillate passes by way of the pipe shown at the top of the hydraulic main, known as the *rising main*, through a

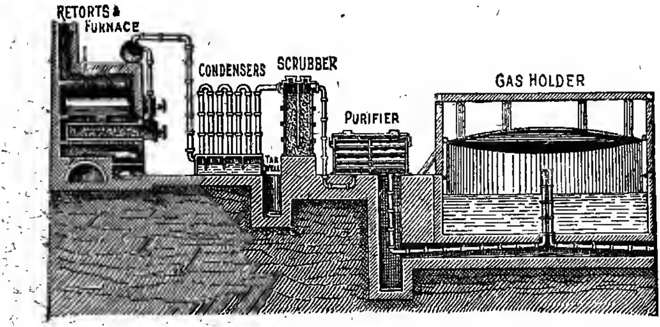

Fig. 2.

series of pipes arranged so that the gas is obliged to traverse the whole length of piping, which may be some hundred yards or more, further quantities of the less volatile constituents being deposited during the passage in the condensing chamber shown below the pipes and thence run off into the tar-well. To avoid loss by leakage of gas through the porous walls of the retorts and to overcome the pressure of the various water-seals through which the gas has to pass, a *pump* (not shown in the figure) is used to extract the gas from the retorts and to draw it through the condensers, while simultaneously providing the pressure necessary to force the gas through the remainder of the working parts of the apparatus.

At this stage of the process, practically all the condensable matters have been removed from the gas, but it still retains substances such as ammonia and carbon dioxide, which are of no value as heating agents or illuminants, and compounds of sulphur, such as sulphuretted hydrogen, which, when burnt, produce sulphur dioxide, a possible source of damage or unpleasantness at the place where the gas is consumed. The removal of the ammonia and part of the dioxide and sulphur compounds is effected by passing the gas through a series of towers, loosely filled with coke, over which a continuous stream of water is made to trickle. This part of the process is termed *scrubbing* the gas. The porous nature of the coke enables a large wet surface to be brought into contact with the gas during its passage through the *scrubber*, thus ensuring almost complete absorption of all gaseous constituents soluble in water. The water from the scrubbers is allowed to flow into the tar-well.

The removal of the remaining sulphur compounds is carried out in the *purifiers*—large iron chambers in which are numerous shelves. These are covered with a layer of damp slack lime, which combines with the sulphide of hydrogen and any residual carbon dioxide to form calcium sulphide and calcium carbonate respectively. It is usual to remove the last traces of sulphur by filling one of the purifiers with brown oxide of iron instead of slaked lime, the substances produced in this case by the reaction between the oxide and the sulphur compounds being the two sulphides of iron and some free sulphur.

The purified gas obtained as described is frequently improved with regard to its illuminating power by the addition of a certain quantity, usually about 20 per cent, of "water-gas" (see par. 44) to which have been added the vapours of heavy hydrocarbons prepared by the "cracking" of oils derived from petroleum. "Cracking" consists of spraying the oil into a heated chamber, where it is partly decomposed, and then passing it into a second chamber, where its decomposition into gases containing a high percentage of carbon is completed. This method of improving the illuminating power of coal-gas is termed the "enrichment" of the gas. Formerly 10 to 15 per cent of cannel coal—a variety found near Wigan, which evolves gas with a high percentage of illuminating constituents—was added to the bituminous coal used for gas-making, but the comparative scarcity of good cannel coal has led to the practice of adding mixed water and oil gases as just mentioned. The mixed gases are purified in similar fashion to the coal-gas and are added after it has left the last purifier. (See also Experiment 35, par. 49.)

The coal-gas is now fitted for delivery to consumers for use. After passing through a very large station meter which records its volume, it is stored in huge *gas-holders*—whose bulky cylindrical shapes form the most striking feature of the works as viewed from outside. The lower edges of the gas-holders are immersed in water and, by means of a system of counterpoising weights and pulleys, the holders move up and down according as they are being filled or are delivering gas for use. Before entering the gas-mains from the gas-holder, the gas passes through a mechanical contrivance known as a *governor*, the function of which is to regulate the pressure at which the gas is allowed to enter the mains to such a value as experience has proved most suitable for ordinary purposes.

6. The further treatment to which the various by-products are subjected can only be briefly indicated. When all the gas has been driven off from the coal in the retorts, the coke remaining is raked out and quenched with water to prevent further combustion. Some part of it may be made use of in the *producer furnace* by which the retorts are heated, while the remainder is sold as fuel for household and factory consumption.

When the temperature at which the coal is distilled is high, as is usually the case, part of the gas evolved suffers decomposition and some of the carbon it contains is set free in the solid state. This is deposited upon the interior of the retorts and is removed therefrom at intervals. It is known as *gas carbon* and is extremely hard and compact. It finds application in electrical work, being used for battery poles and as the conducting pencils in arc lights.

The *coal tar* undergoes a further process of destructive distillation and affords a series of products, among which may be mentioned carbolic acid, creosote, aniline, coal-naphtha, naphthalene and anthracene. From these bodies may be obtained many others, including several of value as colours, perfumes, and flavouring matters. The residue from the coal tar distillation is pitch, a material in considerable demand for the production of asphalt and varnishes.

The *gas liquor* or *ammoniacal liquor*, as the aqueous layer of the contents of the tar-well is termed, is boiled with an alkali—milk of lime—and the ammonia thus expelled in the gaseous form. The gas is passed into sulphuric acid, with which it combines, forming ammonium sulphate. This substance is crystallised out and is largely used in the crude state as manure, since it contains a high proportion of nitrogen in a form suitable for assimilation by plants. From it are also derived all other ammonium compounds of technical importance, such as ammonium chloride and ammonium carbonate, as well as the strong solution of the gas itself in water, known as ammonium hydrate (spirit of hartshorn).

The spent lime from the purifiers is sold under the name of *gas lime* as an insecticide for cleansing soils of such pests as wireworm, and for the improvement of stiff clays. The iron oxide also used in purifying the gas is "regenerated" by exposure to air, whereby oxygen from the air replaces the sulphur, which remains in the free state mixed with the oxide. After several such reoxidations, the proportion of sulphur becomes so high—over 50 per cent—that the material is of no further value as a purifying agent. It is then known as *spent oxide* and is sold to the manufacturers of sulphuric acid, being used by them as a source of the sulphur requisite for the production of that acid.

7. From one ton of coal, about 10,000 cubic feet of gas are commonly produced, while the other chief products are obtained in about the following proportions: coke, 14 cwt., coal tar, 1 cwt., gas liquor, 1½ cwt. The actual quantities obtained in any given case may vary considerably from those mentioned, according to the nature of the coal used and the temperature of distillation, and to a lesser extent with the variations in the details of manufacture as carried out in different works.

It will be noted that there is very little waste involved in the operation of gas-making as roughly outlined above. Formerly great trouble was experienced by gas companies in disposing of the large quantities of tar and gas liquor obtained as by-products, but the researches of modern chemists have entirely altered this state of affairs. The commercial value of the substances previously considered as noxious waste products is probably greater than that of the coal-gas with which the manufacture is primarily concerned. Similar co-operation between the worker in the laboratory and the large scale producer of saleable commodities now exists in all important branches of industry to the mutual advantage of both and the benefit of consumers in general.

8. The ash or incombustible mineral matter which remains after the combustion of wood or charcoal has been completed deserves examination.

Experiment 4. Place the fragment of charcoal obtained in Experiment 1 in a small weighed crucible. Heat the uncovered crucible with its contents strongly with a powerful Bunsen flame until no further combustion occurs. Examine the residue—the ash—when cold. Weigh the crucible and ash, and determine the weight of the ash. The percentage of ash in the fragment of wood originally used (see Experiment 1 for weight of wood) may be easily calculated.

Shake out the ash into a small beaker containing a little distilled water. Dissolve as much of the ash as possible by warming the liquid and agitating the beaker. Test the reaction of the solution produced towards red and blue litmus papers. It will be found to turn red litmus blue. This is due to the presence in the ash of potassium carbonate—a salt with an alkaline reaction.

This substance was formerly produced in large quantities by burning wood and treating the ashes with water. It was used under the name of "potashes" in the manufacture of glass, soap, and other commodities. The ashes of land plants furnish potassium carbonate, while those of seaweed and of plants grown near the sea yield sodium carbonate, another "mild" alkali of great value.

9. When one of the fuels already mentioned is burnt in air, the carbon contained in the fuel combines with the oxygen of the air to form carbon dioxide, while the hydrogen similarly unites with the oxygen and produces hydrogen oxide or steam. Evidence of the formation of these bodies was obtained in Experiment 88, Part I. All the fuels mentioned do not combine with equal readiness. Wood burns much more easily than house coal and the latter more readily than anthracite. To ensure that the combustion of such fuels as coke, charcoal, and anthracite shall be

continuous, it is necessary that a good supply of air shall be furnished. Under certain conditions carbon may form another oxide when burnt. This contains a lesser proportion of oxygen than carbon dioxide and is known as carbon monoxide.

Experiment 5. Fit up apparatus similar to that shown in Fig. 3. Replace the roll of copper gauze

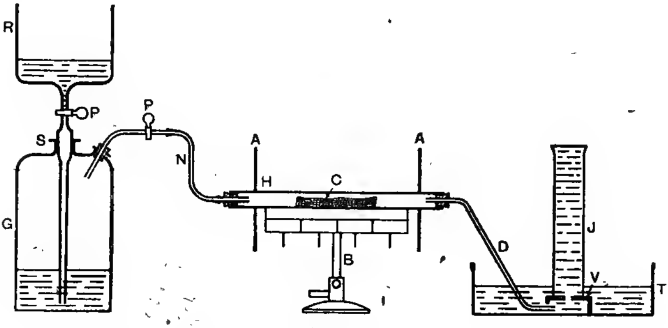

Fig. 3.

*G* = gas-holder filled with air.
*R* = reservoir of gas-holder.
*P*, *P* = well-greased glass stopcocks.
*D* = glass delivery tube.
*A*, *A* = square shields of asbestos millboard.
*H* = piece of hard combustion tubing about 1 ft. long and $\frac{3}{4}$ inch in diameter.
*C* = roll of bright copper gauze about 5 in. long.
*B* = Ramsay burner (a row of Bunsen burners may be substituted for this).
*N* = stout rubber connection.
*J* = large gas-jar.
*T* = earthenware pneumatic trough.
*V* = beehive cell.
*S* = tight-fitting hollow glass stopper.

by a quantity of small pieces of wood charcoal about the size of a large pea. These should fill about six inches of the tube and should be lightly packed together. Keeping the taps *P*, *P* closed, light the burner and gradually raise the temperature of the charcoal to a red heat. It will usually be found that a certain amount of gas is given off during the heating and this should be allowed to escape through the water in the trough. This gas is evolved because the charcoal, when prepared on the commercial scale, is not in general heated sufficiently long to ensure the complete removal of all volatile products of distillation. When bubbles no longer escape from the end of the delivery tube, open the taps and allow a slow stream of air to pass through the hard glass tube from the gas-holder. The rate at which the bubbles should ascend through the water in the trough is about two per second. At the end of a minute, place a gas-jar upon the beehive cell and collect a jar of the gas. Two further jars may be similarly prepared.

Shake up a little lime-water in one jar. The formation of a precipitate will show that some of the carbon has burnt completely, forming carbon dioxide.

Apply a lighted taper to the mouth of another jar. A blue flickering flame will pass slowly down the jar. This affords evidence of a second product of the combustion of the carbon, a gas which is itself combustible. Shake up the contents of this second jar with lime-water. The great increase in the quantity of precipitate formed indicates that the burning of the new gas produces carbon dioxide.

Invert the third jar of gas over a solution of caustic soda or potash in a small glass dish. The liquid will rise a short distance in the jar, but will not reach the top of the jar, however long the latter be left in the solution. (Compare this result with that obtained later in Experiment 12.)

Experiment 6. Arrange the apparatus shown in Fig. 4. The Kipp's generator contains a supply of marble in the middle bulb, and the liquid shown is a mixture of equal parts of commercial hydrochloric acid and water. The carbon dioxide produced by the interaction of the marble and acid is bubbled through water in the wash-bottle in order that the rate at which the gas is passed may be measured. The long wide tube shown over the Ramsay burner may be of hard glass or, preferably, of iron or porcelain. (The tube as figured is somewhat short. The corks should be at least three inches from the ends of the burner.) It is loosely filled with small pieces of charcoal which have been thoroughly heated at a red heat for a considerable time in order to drive off the gasifiable portion of commercial charcoal as completely as possible. The gas issuing from the right-hand end of the combustion tube is passed through a solution of caustic potash,

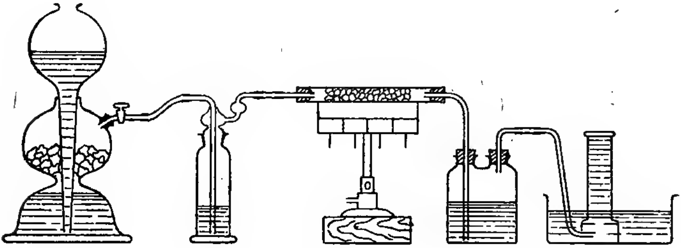

Fig. 4.

containing about 30 g. of potash in 100 c.c., in order to remove any carbon dioxide unacted upon. When the apparatus is ready, pass a steady stream of carbon dioxide until the gas passing into the Woulfe's bottle is practically entirely absorbed by the potash. The air will then have been almost completely displaced from the various parts of the apparatus. Light the burner and allow the carbon dioxide to pass at the rate of about two bubbles a second through the water in the first wash-bottle. Note the behaviour of the gas which enters the potash solution. When this no longer absorbs the major portion of the gas, as shown by bubbles arising frequently in the water in the trough, place a gas-jar upon the beehive cell and collect a jar of the escaping gas. Two further jars may be collected in the same manner. Extinguish the furnace, disconnect the first wash-bottle from the wide tube, and turn off the tap of the generator.

Shake up the contents of one of the jars with lime-water. If the directions have been faithfully carried out, there should be no production of turbidity.

Remove the glass plate from the mouth of a second jar and at once apply a lighted taper. The gas should burn with a characteristic flickering blue flame. As soon as the burning has finished, pour a little lime-water into the jar and shake up. The immediate formation of a considerable quantity of a white precipitate—calcium carbonate—indicates that carbon dioxide has been formed by the combustion of the gas.

Hold a third jar, mouth downwards, and remove the glass plate. At once push in a lighted taper, and observe the behaviour of the taper. It should be extinguished, showing that the gas does not support combustion.

The equations representing the changes that have taken place during the various portions of the above experiment are as follows:

(1) $$\left.\begin{array}{c}\text{Calcium carbonate}\\ \text{(marble)}\\ +\\ \text{hydrogen chloride}\\ \text{(spirit of salt)}\end{array}\right\} = \left\{\begin{array}{c}\text{calcium chloride}\\ +\\ \text{carbon dioxide}\\ +\\ \text{hydrogen oxide.}\end{array}\right.$$

(2) $$\left.\begin{array}{c}\text{Carbon dioxide}\\ +\\ \text{potassium hydroxide}\\ \text{(caustic potash)}\end{array}\right\} = \left\{\begin{array}{c}\text{potassium carbonate}\\ +\\ \text{hydrogen oxide.}\end{array}\right.$$

(3) Carbon dioxide + carbon = carbon monoxide.

(4) Carbon monoxide + oxygen = carbon dioxide.

10. Should any difficulty be experienced in obtaining fairly pure carbon monoxide as a result of the performance of the above experiment, a supply for testing purposes may be readily procured by treating sodium formate with strong sulphuric acid.

**Experiment** 7. The apparatus needed is shown in the accompanying diagram. The acid is added, a little at a time, through the thistle funnel, and the gas is collected in the usual way over water in the pneumatic trough.

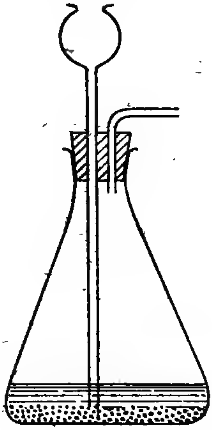

Fig. 5.

$$\left.\begin{array}{c}\text{Sodium formate}\\+\\\text{hydrogen sulphate}\end{array}\right\} = \left\{\begin{array}{c}\text{sodium bisulphate}\\+\\\text{hydrogen oxide}\\+\\\text{carbon monoxide.}\end{array}\right.$$

11. From Experiment 5, it may be easily seen that carbon monoxide is formed during the burning of carbonaceous material if the supply of air—and consequently of oxygen—is comparatively small. Its production in ordinary fires is of frequent occurrence, the typical flickering blue flame of the burning gas being seen hovering over the upper surface of a coke fire, or a coal fire in which the gaseous products of the heating of the fuel have been expelled and burnt, leaving a red-hot mass in the grate. The reason for the formation of the lower oxide of carbon in such cases is readily apparent. The red-hot fuel at the bottom of the fire is in contact with a good supply of air, brought continuously into its neighbourhood by the draught of the chimney. Carbon dioxide is produced in this region and is carried by the air-stream upward over the glowing mass in the centre of the fire. Here some of the dioxide parts with one-half of its oxygen with the consequent formation of the lower oxide. (Cf. Experiment 6.) When the carbon monoxide thus generated reaches the top of the fire, it is brought into contact with a further supply of oxygen contained in the air which is aspirated over the surface of the fire by the action of the upward current in the chimney. Combustion of the lower oxide occurs and carbon dioxide is thus the ultimate result.

When the air-current is powerful, as in the case of the fires under boilers in factories or other works, part of the monoxide may be carried away by the air into the chimney shaft. All carbon carried away in this form represents so much wasted fuel, and great care is exercised in the construction of furnaces and flues so that the combustion may be as complete as possible, or arrangements are made that any escaping gas may be burnt elsewhere in the works.

12. A supply of carbon dioxide for experimental purposes may be obtained by burning charcoal in oxygen, as in Experiment 114, Part I, but it is more usual to prepare the gas by taking advantage of the readiness with which it is evolved when an acid acts upon a carbonate. Thus, when sodium carbonate is acted upon by vinegar, the liquid froths up considerably, owing to the production of much carbon dioxide. The reaction may be considered as occurring in two stages. In the first, sodium acetate and carbonic acid may be looked upon as the products:

$$\left.\begin{array}{c}\text{Sodium carbonate}\\ \text{(washing-soda)}\\ +\\ \text{hydrogen acetate}\\ \text{(vinegar)}\end{array}\right\} = \left\{\begin{array}{c}\text{sodium acetate}\\ +\\ \text{hydrogen carbonate}\\ \text{(carbonic acid)}\end{array}\right.$$

Carbonic acid is, however, unstable except in very dilute solution in water, and by far the greater portion produced at once decomposes into water and carbon dioxide. Thus:

Hydrogen carbonate = hydrogen oxide + carbon dioxide.

The carbonate and acid generally made use of are marble (calcium carbonate) and hydrochloric acid as in Experiment 6.

Experiment 8. Fit up the apparatus shown in Fig. 6. The gas is delivered to the bottom of the gas-jar and, being about one and a half times as heavy as air, collects in the jar, displacing the air upwards. This method of collection of a gas is termed "collection by upward displacement of air". It is commonly used in the case of gases which are heavier than air and are soluble in water, the latter property rendering them unsuited for collection over that liquid.

During collection, the mouth of the jar may be

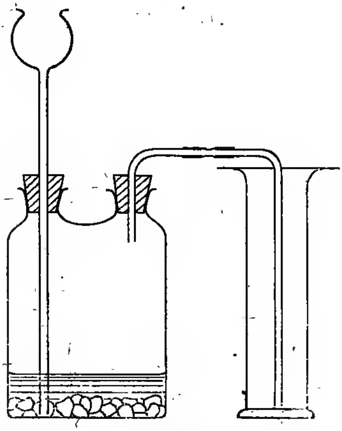

Fig. 6.

loosely closed with a piece of cardboard perforated to permit the passage of the delivery tube. The jar may be judged to be full of the gas when a lighted taper placed at the mouth is immediately extinguished. Collect four jars for use in the following experiments.

Experiment 9. Hold a glass beaker under the mouth of a jar of the gas, remove the plate from the mouth, and allow the gas to fall into the jar. Ascertain that it has done so by thrusting a lighted taper into the beaker. Leave the latter vessel upon the bench with its mouth uncovered, and test the nature of its contents at intervals of a few minutes with a lighted taper.

*Exercise for Student.*

Explain any change in the behaviour of the contents of the beaker with regard to supporting the combustion of the taper.

EXPERIMENT 10. Pour a little clear lime-water into a second jar of the gas. Replace the plate and shake well. Allow the jar to stand for a time.

EXPERIMENT 11. Pour enough distilled water into the third jar to fill one-half of the jar. Thoroughly wet the palm of the hand, place it upon the mouth of the jar (which should be a small one) and vigorously shake the jar with the palm pressed *firmly* in contact with the mouth. If the jar was well filled with gas, it should remain suspended from the palm of the hand after shaking.

*Exercise for Student.*

Explain why the jar remains attached to the palm.

EXPERIMENT 12. Into a small glass dish or large evaporating dish pour sufficient fairly strong caustic soda (or potash) solution to fill half the vessel. Invert a jar of carbon dioxide, place its mouth under the surface of the alkaline liquid, and withdraw the plate. Allow the jar to remain in contact with the solution for some minutes. The liquid will rise rapidly in the jar and, if the latter was well filled with the gas, should at length occupy it almost completely.

*Note.* The caustic alkali will not damage the skin if washed off *at once* in a stream of water from the tap.

*Exercise for Student.*

Write down the equations representing the chemical changes involved in Experiments 8, 10, 11 and 12.

13. Large quantities of carbon dioxide are made during the process of preparing lime from chalk.

Experiment 13. Fit up the apparatus shown in

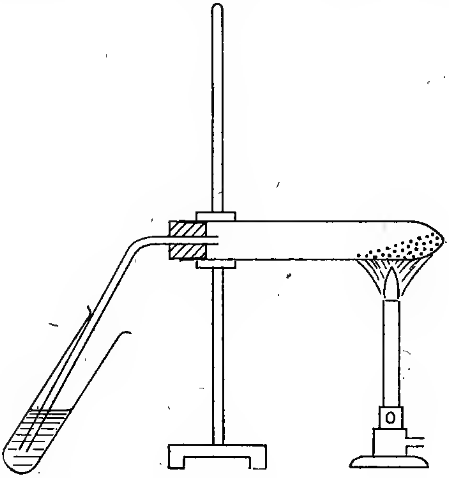

Fig. 7.

Fig. 7. In the hard glass tube place about 1 g. of powdered marble or chalk. The test-tube contains lime-water. On heating the chalk to a red heat, carbon dioxide is driven off, as shown by the turbidity produced in the lime-water. If the heating be continued until no more gas escapes, the residue in the hard glass tube consists of quicklime in the form of powder. To show this, allow the tube to cool, after removing the end of the delivery tube from the lime-water. When cold,

allow a few drops of water to fall into the tube. The lime will be slaked with the production of sufficient heat to make the end of the tube distinctly warm.

Equations:

Calcium carbonate = calcium oxide + carbon dioxide.
(quicklime)

Calcium oxide + hydrogen oxide = calcium hydroxide.
(slaked lime)

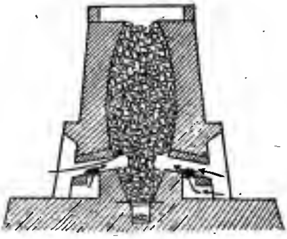

Fig. 8.

On the large scale, this operation is generally carried out in large brick structures known as lime-kilns. Fig. 8 shows such a kiln in section. Limestone and small coal are fed into the kiln in alternate layers. The heat evolved during the combustion of the coal causes the limestone to give off carbon dioxide, which is carried away with the gases formed by the burning of the coal, the lime produced being removed at intervals from the bottom of the kiln.

Another operation which involves the production of much carbon dioxide is brewing. During the fermentation of the sugar solution required for the making of beer, the liquid froths considerably, the gas which causes this being carbon dioxide. (See Experiment 128, Chapter x.) In many breweries the gas is not allowed to escape, but is pumped into strong wrought iron cylinders. The pressure produced within these is sufficient to liquefy the gas, which may thus be conveniently stored. Large quantities of carbon dioxide are used in this form for the aeration of mineral waters and for laboratory purposes as a refrigerant. Great decrease of temperature is produced by the rapid escape of the gas through a small aperture when the valve of the cylinder is opened and part of the escaping gas is solidified at the low temperature reached, and may be obtained as a white snow-like mass by the use of suitable apparatus.

14. The importance of the presence of carbon dioxide in air for the growth of plants, and of that dissolved in water for a similar purpose in the case of water-plants, has been already dealt with (see Part I, par. 164). Animal life is affected by carbon dioxide in quite a different manner. The presence of the gas in air to the extent of 1 per cent seems to cause little inconvenience, provided the gas be pure. The air of mineral water factories may easily contain this proportion, but the employees suffer no discomfort. Increasing the proportion results in the production of deeper inhalation and, when the air is charged with some 6 per cent of the gas, headache, palpitation and other signs of physical distress are produced. Eleven to 12 per cent produces collapse, but death does not supervene rapidly, even with this proportion present in the air breathed. Removal to an atmosphere of pure air brings about recovery, unless the period of subjection to the action of the gas has been prolonged. In the "Grotta del Cane", near Naples, carbon dioxide from subterranean sources exudes through fissures in the floor of the cave and collects in considerable quantity before it is dissipated by diffusion. The amount in the air at the breathing level of a man is insufficient to cause distress, but the unfortunate dogs,

which are led in by the guides, are soon reduced to a state of coma, from which they recover when again taken into the open air. From the above statements it will be seen that the presence of much carbon dioxide in air may be dangerous to the health of those breathing the air. It is incorrect, however, to describe carbon dioxide as a "poisonous" gas. The ill effects produced are not due to any direct toxic effect, but rather to oxygen being present in insufficient proportion for the proper continuance of life.

The case is different with carbon monoxide. This gas is able to combine with the colouring-matter of the red corpuscles of the blood—*haemoglobin*—forming a very stable cherry-red compound known as *carboxyhaemoglobin*. The corpuscles thus affected are no longer capable of performing their proper function as oxygen-carriers throughout the system, and, should sufficient carbon monoxide be inhaled, death soon ensues from suffocation. The lower oxide of carbon may therefore be correctly termed "poisonous".

The great economic importance of the solubility of carbon dioxide in water will be dealt with in Chapter v.

15. During many of the combustions already effected, the production of flame will have been noted. Our next consideration will be the nature of this phenomenon. The first steps may well be of an experimental character.

Experiment 14. Light a candle and examine the flame in a place free from draughts. Two main regions will be readily distinguished—(1) the lower and non-luminous cone immediately surrounding the wick;

(2) the brilliant outer region or "mantle". Careful examination will reveal two further portions—(3) a practically non-luminous sheath which envelops the entire upper part of the flame; (4) a zone of a distinctly blue tint below the inner dark region. The presence of the former may be rendered evident to the eye by holding a card between the eye and the candle so that the light from the luminous mantle is cut off, while the edge of the flame is still visible, when it will appear as a thin faintly yellowish layer.

Examine similarly the flame of a Bunsen burner with the holes which control the air-supply closed. It will be found to consist of four regions comparable to those mentioned, but (4) is less pronounced, while (3) is more readily distinguishable. The above structure is characteristic of the flames of nearly all carbon compounds when burnt with a comparatively limited supply of air.

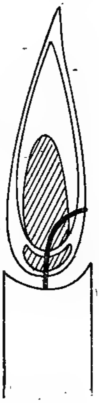

Fig. 9.

Heat a piece of glass tubing about two inches in length in a Bunsen flame for a few seconds. Holding it with a pair of crucible tongs, place one end in the dark cone of the candle flame. Apply a lighted match to the upper end of the tube and a small flame of similar appearance to that of the candle will appear at the end of the tube.

Quickly depress a sheet of stout paper upon a candle flame till the paper is a short distance above the wick. As soon as a scorched ring appears upon the upper surface of the paper, remove it. If this be done carefully, the paper will not ignite, and it will be seen that the interior of the scorched ring consists of undamaged paper.

Hold the under-surface of a clean porcelain dish in a candle flame so that the luminous portion of the flame plays upon the porcelain. At the end of half a minute remove the dish and examine the part which has been in contact with the flame. A considerable deposit of dense black soot will be observed.

16. The observations made in the above experiment assist one to comprehend the nature of the combustion that takes place when flames are formed. A flame is only produced when gaseous or readily vaporisable combustibles are available. The material of a candle is solid at ordinary temperatures, but the heat of the match applied to the wick is sufficient to melt and volatilise a small portion of the adherent fatty matter. The burning of this portion evolves enough further heat to melt the adjacent wax and this, by capillary attraction—a force brought into play whenever porous material is in contact with a liquid—passes up between the strands of the wick. On reaching the flame, the liquid boils and the heat evolved by the burning of the gas thus produced causes the formation of more liquid wax. The process of burning, once started, is thus continuous. The gaseous matter formed is not, however, a simple substance, but a mixture of compounds of carbon and hydrogen, partly derived directly from the wax, and partly produced by the decomposition of some of the more complex of these latter bodies into simpler compounds by the heat. That is to say, destructive distillation (see par. 3) takes place around the wick of the candle. In the dark region practically

no combustion occurs, the supply of admixed air being quite insufficient.

In the luminous mantle, the supply of air is greater and part of the carbon and hydrogen of the hydrocarbons of the inner cone is transformed into the oxides of these elements. The increased temperature in this region causes further decomposition to be set up and part of the carbon is set free in the form of minute solid particles. The brilliance of the candle flame is largely due to the heating of these particles to incandescence—*i.e.* to such a temperature that they give out light—by the heat produced by the burning of some of the carbon and hydrogen in their neighbourhood.

In the outer mantle the combustion of the constituents of the candle is completed. Should the supply of combustible material be properly regulated, the final products are carbon dioxide and water only, but if the wick permit of the ascent of too much melted wax, or the candle be burnt so that an insufficient supply of air reaches the flame, part of the carbon may entirely escape combustion and the candle "smokes". A further cause of "smoking" is to be found in the cooling of the flame by the onrush of a vigorous stream of air, or by the introduction of a cold body into the flame.

EXPERIMENT 15. Make a short coil of several turns of copper wire, such that it is of approximately the same diameter as the candle flame. Hold the free end of this with the tongs and depress it on the flame so that it surrounds the luminous mantle. The brightness of the flame will be very considerably diminished, and much smoke will be produced.

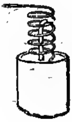
Fig. 10.

Remove the coil and heat it to bright redness in a good Bunsen flame. Transfer it to the candle flame. The loss of luminosity and the quantity of smoke produced will be much less pronounced.

17. All the above experiments should be repeated, using the luminous flame of the Bunsen burner instead of the candle flame. The observations in this case will almost exactly correspond with those already made. Should any differences be noted, it will be an interesting exercise for the operator to endeavour to account for such differences.

18. The structure of the flame of the ordinary Bunsen burner, when the air-supply is opened, is of quite another type from those just considered.

Experiment 16. Light a Bunsen burner and open the hole or holes near the base to their fullest extent. On examining the flame thus produced, it will be found to consist of two well-marked regions—(1) an inner conical portion of a bluish tint; (2) an outer mantle, usually much larger than the inner cone, and of a paler tint of blue. (See Fig. 11.)

That the inner portion is comparatively cool and is composed of unburnt gas, mixed with air, may be shown by testing with a short glass tube and with a sheet of paper as previously described in Experiment 14. That the outer mantle does not contain unburnt particles of carbon may be demonstrated by depressing a clean porcelain dish upon this part of the flame for some seconds. The two parts of the Bunsen flame

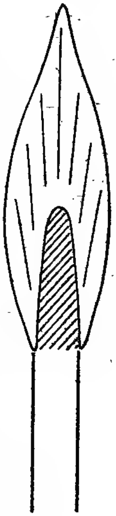

Fig. 11.

hence correspond respectively to the dark part of the candle flame and to the outer mantle where complete combustion takes place. On partly closing the holes at the base of the burner, the appearance of the flame will be similar to that shown in Fig. 12.

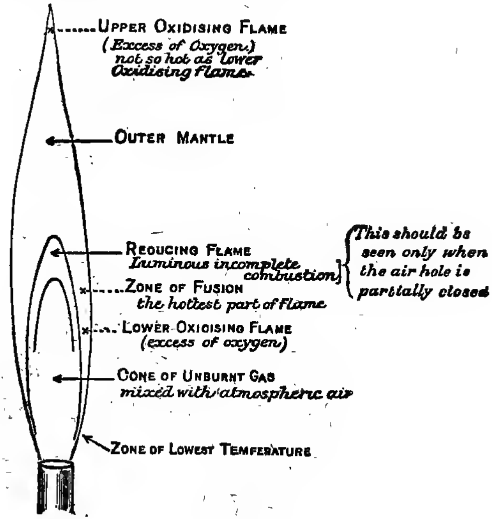

Fig. 12.

19. The absence of a region of incomplete combustion in a fully developed Bunsen flame is chiefly attributable to two causes—(1) the admixture of air with the gas issuing from the aperture of the burner, the quantity of oxygen thereby brought into contact with the gas being greater than that which is found in the inner part of a candle or luminous gas flame; (2) the dilution and consequent cooling of the gas by the air thus introduced.

Experiment 17. To show that an air-current is set up when the air-holes of the burner are opened, light the gas and hold near the holes a piece of smouldering brown paper. In the absence of draughts, some of the smoke from the paper may be seen to be drawn by the air-current into the interior of the burner tube.

Experiment 18. The lessening of pressure in the neighbourhood of the jet of the Bunsen burner, which is the cause of the inrush of air through the air-holes, may be shown more clearly by the following method. Close the air-hole at the base of a burner with a well-fitting piece of wide rubber tubing. In the tubing, immediately opposite the hole, pierce a small hole. Place the end of a small manometer (pressure-gauge), constructed as shown in the diagram, in the hole in the rubber tubing. Turn on the gas and note the behaviour of the water in the pressure-gauge. (To make the movement of the liquid more easily followed, it may be coloured with a little litmus or indigo.) It will be noted that the end of the liquid in the horizontal limb of the manometer will recede in the direction of the burner. On turning off the gas, it will again resume its original position. To obtain a good result, select a burner which gives a strong steady flame when burning with the air-supply wide open.

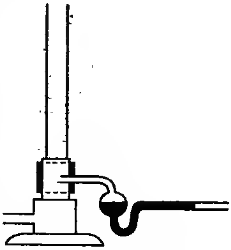
Fig. 13.

Experiment 19. To show that dilution plays a part in the reduction of the luminosity of the flame, the burner fitted with rubber tubing in the preceding experiment may be further utilised. Through the small hole in the rubber tubing insert the end of the delivery tube of a Kipp's generator in which is a supply of marble and hydrochloric acid for the production of carbon dioxide. Light the gas and turn off the gas-supply until the flame is about half its maximum size. A luminous flame will be obtained. Open the tap of the generator and allow a steady stream of carbon dioxide to mix with the gas issuing from the jet of the burner. The admixture of this typically incombustible gas with the coal-gas will result in the loss of much of the brightness of the flame, and, by adjustment of the quantities of carbon dioxide and gas made use of, a flame of a pale blue colour devoid of value as an illuminant may be obtained. From our previous work on the nature of carbon dioxide we may readily infer

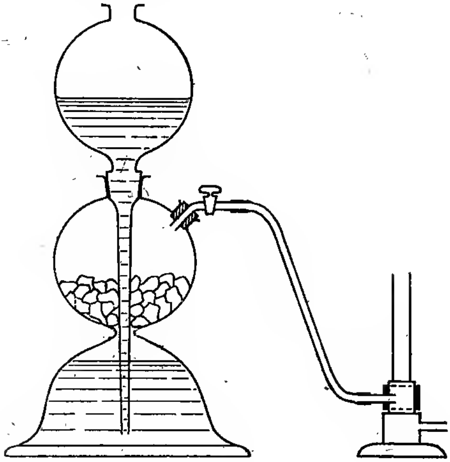

Fig. 14.

that the loss of brightness is not in any way due to more complete combustion of the coal-gas on account of its presence.

20. The Bunsen flame is of great value as a source of heat since it is of high temperature and is smokeless. That its temperature is higher than that of the flame produced when the same quantity of gas is burnt without admixture of air is due to (*a*) the smaller size of the flame and its greater steadiness; (*b*) the smaller proportion of heat lost by radiation to surrounding bodies. The same total quantity of heat is produced in both cases, but in the Bunsen flame this heat is produced within a smaller bulk and is less accessible to the cooling effects of air-currents.

EXPERIMENT 20. Light a Bunsen burner with the air-holes wide open. Note the size of the flame and the resistance which it offers to deflection when the breath is blown strongly against it. Close the air-holes with the thumb and forefinger and note the difference in the volume of the flame and the comparative ease with which it can be blown about.

EXPERIMENT 21. The temperature of the various parts of a Bunsen flame may be roughly gauged by inserting into each part in turn a thin platinum wire. For convenience, the wire may be mounted by fusing it into the end of a glass jet produced by drawing out a piece of tubing as described in Part I, Experiment 46. The varying degrees of brightness of the incandescent wire indicates approximately the temperatures of the various parts of the flame. The hottest regions will be found just above the top of the inner blue cone and near the edge of the flame level with the top of the inner cone, while the middle of the lower part of the cone will not be hot enough to render the wire incandescent. (See Fig. 12, p. 31.)

21. It will have been noted that a mixture of coal-gas and air is formed in the barrel of a Bunsen burner. Such a mixture is frequently of an explosive nature, *i.e.* the total quantity ignites at practically the same instant, producing a very large quantity of heat and thereby causing rapid and enormous expansion of the gaseous products of combustion.

EXPERIMENT 22. Fill a gas-jar of about 200 c.c. capacity with water and invert it over water in the pneumatic trough. Pass coal-gas into the jar by means of a rubber tube attached to the ordinary gas-supply, until the jar contains about one-twentieth of its volume of gas. Slide a glass plate under the mouth of the jar, and remove it from the trough. By sliding the plate on the mouth of the jar so that the mouth is partly opened, allow the water to run out. The jar now contains a mixture of air and coal-gas. Prepare in similar fashion other jars containing respectively one-tenth, one-fifth, one-third, and one-half their volumes of coal-gas, the remainder of the contents of the jar being air in each case. Allow the jars to stand for about half-an-hour, reversing each occasionally, in order to bring about more complete admixture of their contents by diffusion.

Bring a lighted taper to the open mouth of each jar in turn, and notice the nature of the combustion set up. In the case of those jars which contain one-fifth and one-tenth by volume of gas, the explosive character of the reaction will probably be pronounced, but, where the proportion of gas is higher, the mixture burns quietly, while that in the first jar shows little, if any, sign of combustion.

From the above observations it is evident that all mixtures of air and coal-gas are not of an explosive character. Under ordinary conditions, the flame of a Bunsen burner burns continuously without sign of explosion, but this phenomenon does occur occasionally.

EXPERIMENT 23. Choose a Bunsen burner which produces a "roaring" flame when the gas and air supplies are both full on. Having obtained such a flame, turn off the gas-supply gradually. The flame will become unsteady and at length will suddenly recede down the tube, with the result that usually the gas issuing from the jet at the bottom of the tube is ignited and burns with a peculiar noisy flame.

This phenomenon of "striking back" or "burning below", as it is variously termed, is really of the nature of a small explosion. To prevent the flame striking back when the gas is lowered, the air-holes should be partly closed *before* lessening the supply of gas.

Another simple but striking experiment may be performed which will further illustrate this point.

EXPERIMENT 24. Fit a large-mouthed bell-jar with a cork through which passes a short length of wide glass tubing as shown in Fig. 15. Stand the bell-jar in a little water in a plate, and fill the jar with coal-gas by attaching the glass tube to the bench-supply by means of rubber tubing and turning on the gas for about 30 seconds. Disconnect the rubber tubing from the glass tube, raise the bell-jar from the water, and apply a lighted taper to the top of the tube. The coal-gas, being of lesser density than air, will pass upwards through the tube and ignite. The flame will be at first luminous and unsteady, but will gradually assume the appearance of a Bunsen flame as the issuing gas becomes mixed with air. At a later stage the inner blue cone of the flame will be seen to pass suddenly down the tube and the contents of the jar will then ignite with a distinct but harmless explosion.

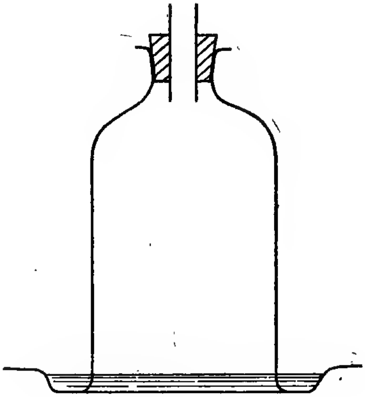

Fig. 15.

In both the experiments just described, the mixture of coal-gas and air issues from the end of the tube with a certain velocity. The issuing mixture is explosive, but the flame does not strike back at once, when the mixture is lit. In explanation of this, it may be stated that for every explosive mixture there is a certain velocity with which the explosion travels in the mixture. As long as the gaseous mixture issuing from the end of the tube is travelling faster than the rate at which the explosion wave corresponding to that mixture travels, no explosion occurs. When the gas-supply of the

Bunsen burner is lessened, the rate at which the mixture passes up the barrel of the burner is also decreased. When the mixture moves more slowly than the explosion wave, explosion occurs and the flame strikes back. Similarly, the mixture of gas and air leaves the glass tube in the last experiment at a speed which diminishes as the experiment proceeds. The mixture becomes richer and richer in air, and consequently more explosive, as the burning continues. The rate at which the explosion travels in the mixture increases as the proportion of air becomes greater and at length a stage is reached at which the velocity of the explosion wave becomes greater than that of the issuing gaseous mixture, and the flame travels down the tube.

22. Other forms of burner have been devised, upon the Bunsen principle, in which, by better admixture of the gas and air, before combustion, higher flame temperatures may be attained. Fig. 16 represents the Teclu burner. In this the air is admitted between the lower edge of the conical base of the burner-tube and that of the large milled nut which travels on the screw-thread worked upon the exterior of the jet. Variation of the quantity of air supplied is effected by turning this nut upward or downward on the thread.

Fig. 17 shows a Meker burner. The air is admitted through several holes instead of one or two, as in the usual forms of Bunsen burner, thus ensuring both a larger supply of air and more complete admixture. The widened top of the burner is further provided with a stout nickel grid which is arranged is such a way that the issuing stream of gas and air is divided into numerous smaller streams. Each streamlet produces a small Bunsen flame when ignited, the inner blue cones of which can be separately distinguished. The outer envelopes are, however, intermingled and form a "solid" flame of great heating power. The Meker flame burns entirely without noise, being in this respect at a great advantage as compared with the Teclu or with an ordinary Bunsen when producing its most efficient heating flame. The presence of the grid prevents striking back, in spite of the high proportion of air contained in the mixed gases issuing from the top of the burner.

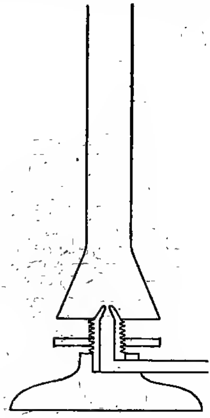

Fig. 16.

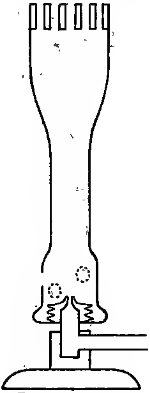

Fig. 17.

23. In ordinary life we consider coal-gas as a combustible substance, while air is looked upon as incombustible and is termed a "supporter of combustion". The parts played by the coal-gas and air are convertible, as may be demonstrated by performing the following experiment.

Experiment 25. Fit a wide glass lamp-chimney with two corks, bored to receive glass tubes as shown in Fig. 18 on the next page. Connect the smaller of the tubes at the lower end of the chimney with the gas-supply. Cover the end of the upper tube with a stout card. Turn on the gas for a few seconds, and then apply a lighted taper to the bottom of the larger tube. Immediately turn off the gas until the flame produced is reduced to one-half its bulk. Remove the card and apply a light to the gas which will now issue from the upper tube. Note the behaviour of the lower flame. It will be seen to pass up the lower tube and will continue to burn within the chimney. (Should this not happen as described, the desired effect may be brought about by gradual adjustment of the supply of gas.)

The flame at the top of the chimney resembles closely the ordinary luminous flame of coal-gas burning in air. The flame within the chimney is evidently of a different character. It is, in fact, a flame of ordinary air burning in an atmosphere of coal-gas. That air is actually passing up the lower tube may be shown by bringing a smouldering piece of brown paper near the bottom of the tube.

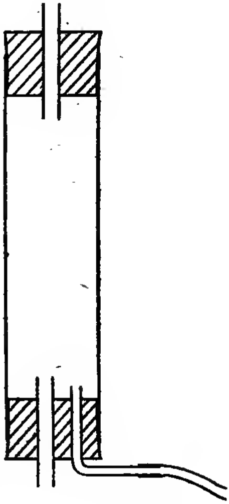

Fig. 18.

By diminishing the supply of gas, the top flame may be caused to become less in bulk, and simultaneously an increase may be noted in the size of the lower flame. Further diminution of the amount of gas allowed to enter the chimney will effect the disappearance of the luminosity of the upper flame, which will become very similar in character to that produced by diluting coal-gas with carbon dioxide in Experiment 19, and will finally be extinguished.

*Exercise for Student.*

What evidence may be obtained from the above experiment as to the nature of the products of combustion of the flame of air burning in coal-gas?

Combustion, then, is a reciprocal phenomenon, *i.e.* a gas may be called "combustible" or a "supporter of combustion", according to the circumstances under which the combustion is effected. That this should be so is due to the fact that combustion of gases is simply a case of chemical combination in which the heat given out during the combination causes the production of flame in the region where the two gases are in contact. We use the phrase "carbon combines with oxygen" interchangeably with "oxygen combines with carbon" and similarly there is no distinction, as regards the chemical change involved, between the statements "coal-gas burns in air" and "air burns in coal-gas".

In the succeeding chapters some applications of what we have learnt about the nature of combustion and flame will be applied to problems connected with ventilating, warming, and lighting the house.

## QUESTIONS

1. What are the usual products of the combustion of all ordinary fuels? How would you show that the substances you mention are actually formed when coal is burnt?

2. What experiments would you perform in order to discover whether a certain lump of coal was anthracite or not?

3. What are the chief substances obtained in the process of dry distillation of wood?

4. Why does a candle flame deposit soot upon the outside of a clean cold vessel held in the flame, while placing the vessel in the flame of a gas-stove produces no such deposit?

5. A sample of coal which leaves a large proportion of ash is usually looked upon as being less economical to use than one which leaves little residue when burnt. Give reasons for the correctness of this view.

6. Describe in outline the manufacture of coal-gas, giving a clear diagram showing the various parts of the necessary plant.

7. Name the most important by-products of the manufacture of coal-gas. What useful substances are derived from these by-products?

8. State the conditions requisite for the complete combustion of ordinary fuels. What substances are formed when such fuels are incompletely burnt?

9. By what tests may it be shown that the gas contained in three gas-jars is carbon monoxide?

10. Sketch the apparatus you would employ to obtain a supply of carbon dioxide, and show clearly how this gas may be distinguished from nitrogen.

11. Why is the flame of a Bunsen burner hotter when the air-supply is open than when it is closed?

12. What is the chief cause of the luminosity of a candle flame? Describe experiments which bear out your statement.

13. Paraffin oil contains carbon and hydrogen. What evidence can you bring forward in support of this statement?

14. Explain why a Bunsen flame sometimes strikes back. How may this behaviour be prevented?

15. What would happen if a lighted lamp were brought into a room *full* of coal-gas? Give reasons for your opinion.

# CHAPTER II

## VENTILATION

24. The cause of the sensations of discomfort experienced in ill-ventilated chambers has long been the object of man's speculation and has given rise to much experimental work of the highest value from the point of view of hygiene. In the early days of modern chemistry, the prominent place occupied by oxygen in the scheme of Nature was clearly grasped by many observers, and the virtues of this element were, if possible, overrated. The proportion of oxygen in the air was adopted as the criterion of its "goodness", *i.e.* fitness for the respiration of man and animals. Hence arose the use of the eudiometer ("goodness-measurer") to determine the amount of oxygen present by volume in a given sample of air. The advent of more refined methods of measurement showed that the variations in oxygen-content were really very small, and quite insufficient to account for the ill effects known to be produced by breathing the air of crowded rooms, mines, and similar places.

The rôle of oxygen was now transferred to carbon dioxide. This gas was recognised as one of the principal constituents of respired air, and the unpleasant stuffiness of crowded rooms was ascribed to the presence of excess of carbon dioxide. Further investigation proved that the gas in the pure state was incapable of producing discomfort, unless present in much higher proportion than occurs even in the worst ventilated spaces. (See Chapter I, par. 14.)

It was next suggested that the trouble arising from bad ventilation was due to the organic matters which escaped from the body during respiration—both from the lungs and the skin. These were supposed to be of more or less poisonous character, the emanations of any single person being of little danger to that person, but affecting others much more severely. It has been shown that the emanations from a healthy person are not by any means of so harmful a character as was at first assumed, and consequently it has been necessary to seek for other causes of the evils which are undoubtedly attendant on the neglect of proper regard being paid to ventilation in all inhabited rooms.

25. The modern view of this matter may be briefly summed up as follows: Healthy conditions of existence may only be attained in enclosed spaces when due attention is paid to the (1) regulation of the temperature to the proper degree of coolness; (2) prevention of stagnation of the air by inducing air-currents of suitable strength; (3) keeping the degree of saturation of the air with moisture at the proper amount; (4) reduction of the proportionate number of pathogenic, *i.e.* "disease-producing", bacteria (*v.* Chapter XII) to as low a figure as possible. Each of these points receives further consideration in the following pages.

26. The human body is capable of continuing its functions without serious inconvenience in the face of very considerable variations in the temperature of its immediate surroundings, provided that it is in a fairly healthy state, and is able to protect itself against extreme heat and cold by changing the nature and

quantity of its coverings. In Polar regions, temperatures as low as – 40° C. are endured by explorers well wrapped in skins, while in a Turkish bath, the naked body may be exposed to a temperature of 50° C. for some time. The general consensus of opinion, however, is that, for persons inhabiting temperate climes such as our own, it is desirable to maintain the temperature of the interior of dwelling houses at about 15° C. (or 60° F.) in order to minimise the risk of discomfort and disease.

The methods by which the necessary adjustment of temperature to this figure are effected in winter belong to the question of warming the house, and will be dealt with in a later chapter. During very hot summer weather it is not of course always feasible to reduce the living-room temperature to 15° C., but it is usual to approximate as closely as may be to this standard by opening all windows, doors, and other inlets or outlets for air, to their fullest extent.

27. The prevention of the accumulation of stagnant air is perhaps the most important matter to be considered in dealing with this subject of ventilation. As already mentioned, the body gets rid of waste products by means of both the lungs and the skin. In the absence of movements of the surrounding air, the moisture-laden emanations from the latter are not removed from the neighbourhood of the body and a layer of damp foul air is soon formed over the whole of the body-surface, especially where it is protected by clothes, the materials of which entangle and retain it readily. It is found that, under such conditions, a feeling of discomfort is soon set up, which increases with prolongation of the period of exposure to the

given conditions. Lowering of general vitality ensues, with consequent diminution of the power of the body to resist adverse circumstances, such as the attack of pathogenic bacteria.

Practically all methods of ventilation in general use have as their object the provision of a supply of air in motion. In most cases, advantage is taken of natural forces, such as convection and diffusion, to bring about the air-currents, and it is usual to group such methods under the heading of "Natural" systems of ventilation. Where large buildings, occupied by many persons, require ventilating, special machinery is made use of, and such systems are considered as "Artificial".

28. Reference to the experimental work performed when dealing with the subject of convection in fluids in Part I, Chapter XI, will be sufficient to enable the reader to comprehend readily how house-ventilation may be effected by this process.

The air heated by the fire expands and becomes of lesser density. The column of air contained in the chimney weighs less than a similar column of the external air. As a consequence, the pressure of the air-column in the chimney is also less than that outside it, and movement of air is set up from the region of greater to that of lesser pressure, *i.e.* from the room towards the chimney base. The cooler air from the room on reaching the fire-place is warmed in its turn by the fire and the difference of pressure inside and outside the chimney is thus maintained, with the result that a continuous stream of cold air moves towards the fire-place as long as the fire remains alight. Since the air thus brought to the neighbourhood of the fire is removed from the room by way of the chimney, a further supply of air is forced into the room through the apertures in its walls by the external atmospheric pressure, and thus the prime requirement of constant motion of the air in the chamber is satisfied. Should the walls of the room be made of impervious material entirely free from openings, it is evident that the supply of air cannot be renewed, and in such a case the fire will not burn properly. It is thus occasionally possible to improve the burning of a smoky fire by judiciously providing a larger air-supply by opening a window or door.

A similar explanation applies to the action of all stoves which possess a flue connected with the outer air, with regard to their function in assisting to keep the room well ventilated.

In the case of stoves not provided with a flue, the air is kept in motion by the convection currents set up by the stove, but the same air may be warmed and cooled repeatedly, and hence less fresh air needs to be introduced into the room. Further, the air itself usually rises considerably in temperature as a result of this method of heating a room, and as this increase of temperature is not necessarily followed by a corresponding increase in the quantity of aqueous vapour contained in the air (see Part I, Chapter XIV, pars. 160–162), the latter soon becomes unpleasantly dry. Evaporation of moisture from the surface of the skin is rendered unduly rapid, with readily noticeable resultant discomfort. On these two counts, closed stoves compare very unfavourably as ventilating agents with open grates.

Steam and hot-water "radiators" act in much the same way as flueless stoves, but are even less efficient as ventilators, since they require no supply of air whatever in order to maintain their value as heating agents. Hence the best aids to ventilation are an ordinary open fire or a well-fitted modern gas-stove provided with a flue.

29. In order to show that air-currents exist in a room heated by an ordinary fire, the following simple experiment may be performed.

EXPERIMENT 26. Place a lighted candle in each of the following positions in turn in such a room, and note the direction in which the flame is deflected in each case.

(*a*) On the hearth in front of the fire.
(*b*) On the floor near the wall opposite the fire-place.
(*c*) Near the top of the door when closed and when open.
(*d*) Near the bottom of the door in both cases as above.
(*e*) Near the top of the window when slightly opened.
(*f*) Near the bottom of the slightly opened window.
(*g*) Near the middle of the window when the top and bottom are both slightly opened.
(*h*) At the keyhole of the door.
(*i*) At any other part of the room desired, such as the middle of the floor, middle of each side-wall, etc.

Deflection of the flame towards the interior of the room, when the candle is held near any opening in the walls, will of course denote an inlet for cool air, while bending of the flame away from the centre of the room will show that air is escaping from that opening. (The directions of the air-currents are better shown if the smoke produced by the burning of an aromatic pastille, or a piece of aromatic paper, be used as an indicator instead of the flame of a candle.)

In general, it will be found that openings near the top of the room act as outlets, while those near the floor are inlets, those at intermediate levels often affording indications varying with the direction of the wind, the difference of temperature between the interior of the room and that prevailing outside, or with some other factor.

*Exercise for Student.*

Try to account for any indications obtained in your actual experiment which are not in accord with the generalisations given in the text.

Similar experiments to the above should be performed in rooms heated by other means, such as gas-stoves, closed coke or anthracite stoves, and hot-water or steam pipes.

30. The most suitable inlet for air is provided by the open window. This should be opened both at top and bottom in order to obtain the best conditions, but it is found that, in very cold weather, such opening at the bottom is often impracticable on account of the strong inrush of cold air through the lower opening. In this case the interposition of a wooden slab under the lower sash, so that the opening is entirely closed by the slab (see Fig. 19), will allow air to enter between the sashes at the middle of the window. Such air,

being deflected in an upward direction by the glass, does not fall so directly upon the heads of those seated near the window and hence less inconvenience is felt. Windows are sometimes fitted with a projecting piece of wood, which subserves the same function as the wooden slab just mentioned. This form of ventilator is known as Hinckes-Bird's ventilator, from the name of the doctor who suggested it.

Many other forms of ventilator have been devised to assist in properly supplying air where it cannot be done thoroughly by means of open windows. It must be remembered that such ventilators are only of service in so far as they keep the air of the room in motion and thus prevent stagnation. Hence small openings are of little avail, and only those forms will be described which provide apertures of sufficient size to allow of the passage of air rapidly enough and in sufficient quantity to be of service in this respect. They should rarely be a necessary part of the equipment of an ordinary dwelling-house, and should be

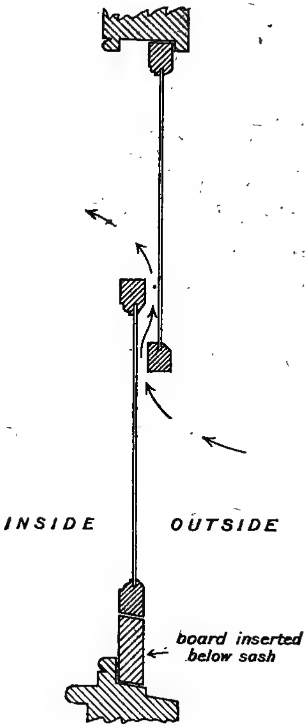

Fig. 19.

fitted only in exceptional circumstances, *e.g.* in bedrooms not provided with a fireplace.

A. *Sheringham's valve.* This consists of a flap of metal, hinged along its lower edge, fixed to the wall of a room opposite an opening of corresponding size in the wall. (See Fig. 20.) By means of a small counterpoise, the flap may be lowered and air permitted to pass into the room. The sloping position of the flap causes the air impinging upon it to take an upward direction. The outer face of the wall is provided with a metal grating, and this should consist of large apertures, which should be kept as free as possible from dust. This ventilator, being intended as an inlet, should be fixed at such a height that it will serve this end and yet not so low that the incoming air will fall too directly upon the heads of the occupants of the room.

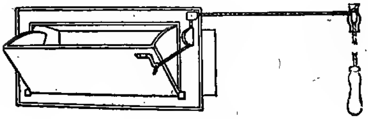

Fig. 20.

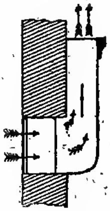

Fig. 21.

B. *Tobin's tube.* A vertical metal tube, which should be of considerable cross-section and not too long, is placed against the inner face of one wall of the room, and at its lower end is bent in a gradual curve so that it may pass through the wall. (See Fig. 21.) The opening on the outer face of the wall is provided with a grating, which should not be of fine-meshed gauze, but of narrow metal strips with wide openings between them. The inner opening is horizontal and should not be closed by a perforated plate or other apparatus which may interrupt and lessen the inflow of air. The entrance of a certain amount of dust or soot from the outer air is of less importance from the point of view of health than the need for keeping the air in a state of continual movement.

A system of Tobin's tubes, combined with an arrangement for the extraction of foul air at the topmost part of the room, such as a tube running from the centre of the ceiling between this and the floor above to the outer wall, may be of considerable service in rendering fit for respiration the air of a large room occupied by many people.

31. It must be remembered that, whatever system of aids to ventilation be in use, and wherever the openings are situated, the presence of a fire in the room will in general cause the chimney to act as the sole outlet, all other openings being thus converted into inlets. In windy weather, moreover, even when no fire is burning in the grate, a marked upward air-current due to aspiration is set up within the chimney. That is to say, the passage of a large mass of air over the relatively small opening at the top of the chimney causes a decrease of pressure near the top of the latter (cf. Experiment 18, Chapter I), with the result that motion of the air in the chimney towards the region of lesser pressure ensues.

Another point worthy of notice is that, in houses constructed upon the usual plan, all stairways being arranged in one large central shaft, this shaft by virtue of its comparatively great length, acts as a flue, air from all the rooms on the lower floors being carried upwards and discharged from the openings present in the highest floors. In some cases the difference of pressure is sufficiently great to extract air even from beneath the floors of the lowest rooms through the cracks in the latter. This air is usually laden with much moisture and in some houses with the products of the decay of organic matter in the soil beneath the house. It is of importance that the accidental entrance of ground air into a house should be prevented as far as possible, and that the air under the house should not be allowed to become stagnant. Proper ventilation of the space beneath the ground floors requires as much care as that of the house in general. It is commonly effected by placing "air bricks", *i.e.* spaces of the size of a brick in the thickness of the wall, fitted with gratings, on all the exterior walls of the house, immediately beneath the floors of the lowest rooms. Such air bricks should be carefully protected from being choked with earth or other matter, and should be tested from time to time in order to discover whether they are performing their function properly.

EXPERIMENT 27. Test whether the air bricks beneath the floors of any available dwelling are working by holding the hand or a lighted taper near each in turn. Note the direction of the air current from each hole and the direction of the wind at the time of experiment. If possible repeat the test on another day when the prevailing wind is coming from another direction.

32. Artificial systems of ventilation have no place in ordinary houses. They are of use in the case of large buildings or of ships which cannot be effectively

ventilated by taking advantage of the ordinary methods of setting up convection currents. In the "Plenum" systems, air is warmed and forced into the room or rooms to be ventilated by means of a powerful fan, and flues are generally provided also for the extraction of the befouled air. In the "Vacuum" systems, the foul air is extracted by a fan or fans, and inlets are in general provided by which warmed air may enter to replace that withdrawn.

33. The process of diffusion plays a part, although a subordinate one, in the process of ventilation. The materials of which houses are constructed are usually more or less porous, and we have already learnt in Part I, Chapter V, that gases pass through such materials. The following experiment will serve to illustrate this point.

EXPERIMENT 28. Fill two jars of equal size, one with dry ammonia and the other with dry hydrogen chloride. (See Chapters VI and XI.) Remove the glass plate from the mouth of the jar of hydrogen chloride, and replace it by an unglazed plate or tile. Invert the jar of ammonia gas, remove its plate and place it, mouth downwards, upon the upper surface of the porous plate, immediately above the mouth of the other jar. The ammonia is lighter than the hydrogen chloride, but slowly mixes with it, the process of admixture being clearly shown by the formation of white fumes in each jar. These fumes consist of solid particles of

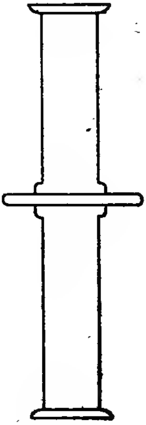

Fig. 22.

ammonium chloride, the compound formed by the chemical union of the two gases.

Houses built of brick afford, when the inner walls are either distempered or covered with unvarnished paper, a certain amount of scope for the process of diffusion to go on. Stone walls are less pervious, and the walls of buildings constructed of metal, such as galvanised iron, allow very little diffusion to occur. The plaster of ceilings is also sufficiently porous to permit of diffusion readily taking place, and the current of hot air from a gas-burner, carrying with it burnt particles of dust, is largely absorbed by the ceiling material, the brown patch left being evidence of the stoppage of burnt matter which cannot pass through the pores of the plaster.

Wet brick, and wet porous material in general, possesses much less efficacy as a diffusive medium than does the dry substance. It follows that the walls of a house should be kept as dry as possible on this count alone, irrespective of other dangers arising from their dampness.

Other matters incidental to the proper ventilation of a house will be taken up in conjunction with the description of the chief methods of heating and lighting now in use as given in the following chapters.

## QUESTIONS

1. Why is it necessary to change the air of living-rooms frequently?

2. Describe what you consider the best method of ventilating a sitting-room and a bed-room.

3. Explain the action of any form of ventilator with which you are acquainted.

4. By what experiment would you try to prove that bricks are made of porous material?

5. What are the uses of the flue of an ordinary fire-place?

6. Suggest an explanation of the formation of a downward current of air in a chimney situated upon a north wall, the fire being unlighted.

7. What natural forces are made use of in promoting the proper ventilation of a dwelling-house? Explain the way in which each acts, and describe an experiment in illustration of the action of each force you mention.

8. What becomes of the carbon dioxide produced by the burning of coal in an open grate?

9. How do you account for the occasional occurrence of an upward current of air in a chimney over an unlighted fire?

10. Why should gas and anthracite stoves be provided with flues?

11. In a room heated by a closed stove a vessel of water is often placed upon or near the stove. Suggest the reason for this practice.

# CHAPTER III

## HEATING

34. The heating, lighting, and ventilation of a house are largely interdependent, and much of the matter dealt with in this chapter has a bearing on the subject considered in Chapter II. In Part I, Chapter XI, it was shown that heat may be transmitted by three different methods—conduction, convection, and radiation. Each of these plays a part in the heating of a house, that of conduction being least prominent. It should be noted that the lighting of the house is effected by means of agents which are also sources of heat and in fact the greater part of the energy generated by the ordinary sources of light is produced in the form of heat. Light is actually transmitted by rays which are similar in character to those of radiant heat, and light rays themselves are capable of raising the temperature of bodies with which they come in contact, though to a lesser degree than the radiant heat rays.

35. We will first examine the effect upon the human economy of the supply of artificial heat by the two methods of radiation and convection. The former is the method of Nature. Heat from the Sun passes to the Earth in the form of rays which do not appreciably heat the Earth's atmosphere while travelling through it. In order that this heat may become apparent to our senses, the interposition of an object in the path of the rays is needed. The energy of the heat rays is

in part absorbed by such an object and is used to raise its temperature. The surrounding air is then warmed by conduction with the result that convection currents are set up in the air, which is thus in course of time raised in temperature. Since the air receives its heat from the objects in contact with it, it is in general at a lower temperature than the ground and the other bodies upon which the rays from the Sun impinge.

Artificial heating by radiation is the mode of chief importance in the case of the open coal fire—the usual system of warming living-rooms in vogue in this country. The walls and the furniture become warm, but the air of the room remains comparatively cool. In this way the indoor conditions are made to resemble those existing outside, and hence little strain is imposed upon the bodily functions as they are not called upon to adjust themselves to a new set of conditions. The coolness of the air has a stimulant effect upon the skin, and the danger of chill arising from the body being much warmer than its surroundings is considerably mitigated. It will be seen that the prejudice in favour of the open fire is not merely sentimental, but has a sound and reasonable basis.

Where the system of heating adopted provides that convection shall be the chief means whereby heat is transmitted, as in warming a building by hot-water or steam pipes, the air in contact with the hot pipes is first heated by conduction and the convection currents thereby set up cause the heat to be carried to all parts of the room by the warmed air. The air itself is thus at a higher temperature than the walls and furniture, and these latter frequently remain comparatively cold. A person seated near an outer wall may be surrounded by air at a much higher temperature than is the case in a room heated by an open fire, yet may suffer a chill through losing heat by radiation from the body to the cold wall. Warm air is not so pleasant to breathe as cool air, and often engenders a feeling of lassitude in those inhabiting rooms warmed by convection systems.

From the above remarks it will be inferred that, other things being equal, it is preferable to heat the rooms of ordinary dwelling-houses by methods which provide that the greater part of the heat supplied shall be in the form of radiant heat. In the following paragraphs the merits and demerits of various heating appliances will be put forward.

36. We have seen that the open coal fire has much to recommend it from the point of view of health and comfort. The chief drawbacks associated with it are that it is a wasteful method of heating and that it involves the production of much dust, with the consequent need for considerable labour to be expended in cleaning. Modern grates are now constructed so as to minimise as far as possible the wastage of heat by making the front of the grate as wide as convenient, lessening its depth as far as can well be done, making use of as much firebrick as possible in its construction, and rendering the opening to the flue adjustable to the least size compatible with the provision of sufficient draught. Fig. 23 shows the construction and appearance of such a form of grate. The use of firebrick increases the radiating power of the grate and lessens the loss of heat by conduction. The metal parts of the grate are usually covered with a layer of black-lead, the object of this being to improve the radiation from

the surface of the hot metal, as well as to preserve it from rust.

Most of the heat wasted escapes with the large volume of warm air which passes up the chimney and, in the older forms of grate, the amount thus lost was increased by the bottom of the grate being open, thus allowing a stream of cold air to pass beneath the burning mass in the grate and to be forced upward

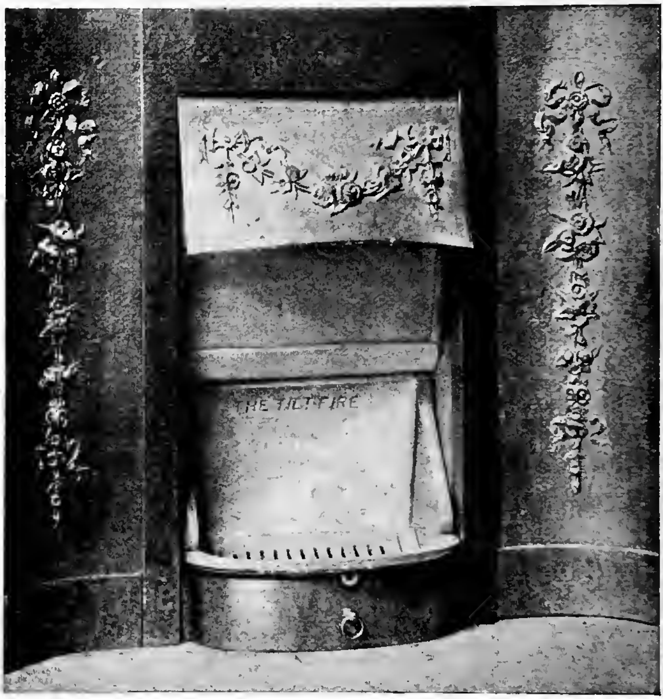

Fig. 23.

through it in greater quantity than was absolutely required for the purposes of combustion of the fuel. In later forms, this is prevented by a movable iron door being provided by means of which the bottom of the grate may be practically closed as soon as the fire is burning brightly. The use of this contrivance, commonly termed an "economiser", also prevents the fuel from being burnt as quickly as was the case in the earlier patterns of stove, *i.e.* combustion is equally complete, yet less rapid, while the amount of heat available for the purpose of warming the room is increased without at the same time a larger supply of fuel being demanded.

37. Many other methods of rendering the open grate less wasteful in its action have been put forward, of which two deserve special mention.

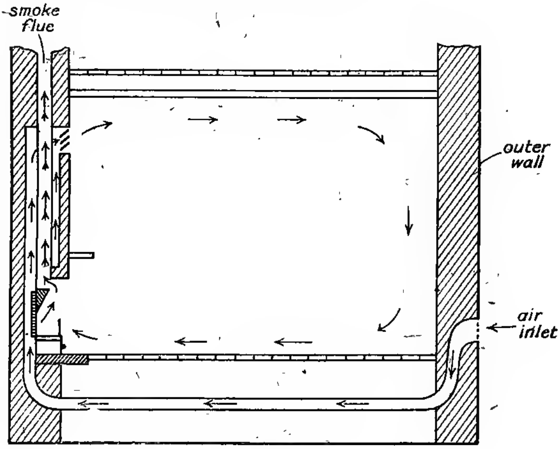

Fig. 24.

In the first, due to Sir Francis Galton, the chimney flue is surrounded by an air-chamber, as indicated in Fig. 24, the latter being in direct communication with the outer air near the bottom of the chamber, and also communicating with the interior of the room to be warmed by means of an opening in the face of the wall, usually situated immediately over the fire-place. The incoming air is warmed by its passage over the heated brickwork of the chimney, and entering the room at a considerable height from the floor, slowly descends as it cools and parts with its heat to the contents of the room. The heating in such a case is a combination of radiation and convection methods, and in winter the ventilation of the room is assisted without the inconvenience often experienced through the entry of very cold air-currents.

The second method of economising the heat from the open stove is of more modern contrivance and consists in having a boiler suitably enclosed within the lower portion of the flue, this boiler being connected with a series of pipes which pass to other parts of the house and are expanded in coils in the various rooms as so-called "radiators". In fact, the arrangement consists of a hot-water system on a small scale, and may be of great service in warming bedrooms, halls, and the like without materially increasing the quantity of fuel consumed. Similar contrivances may be obtained, whereby the domestic hot-water supply is arranged in series with a number of radiators, the source of heat being in this case the kitchen range—commonly a most expensive coal consumer.

38. A praiseworthy attempt at making the greatest possible use of the heat supplied by a given quantity of fuel is afforded by the neat combination stove

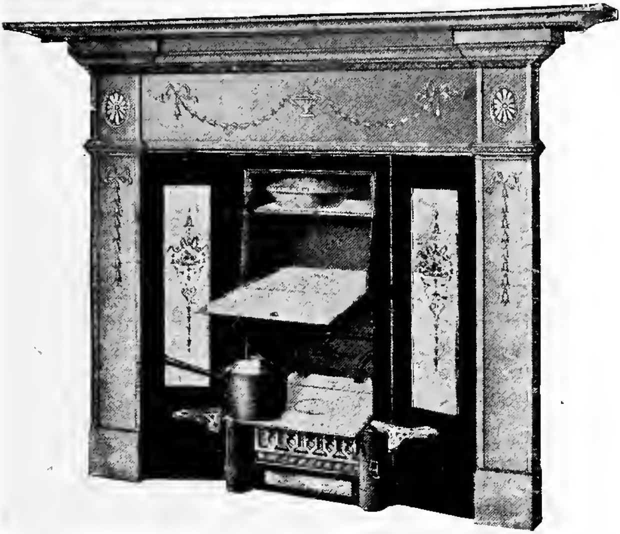

Fig. 25.

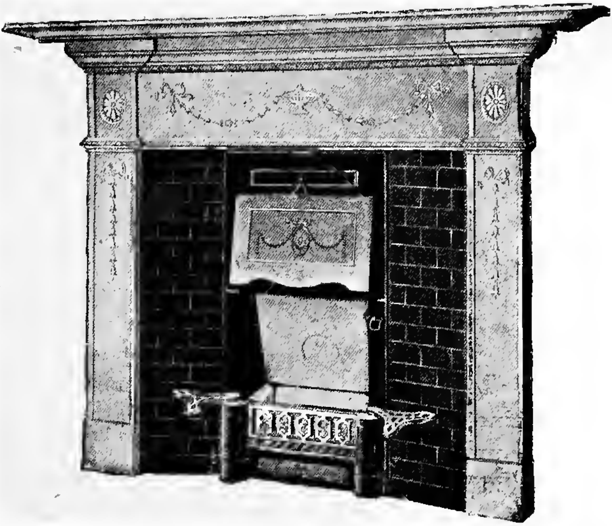

Fig. 26.

shown on page 63. It is especially suitable for small households in which little outside help is available. The figures show the general appearance and construction of the stove, which is known as the "Interoven". A small boiler at the back of the grate affords a sufficient supply of hot water for the wants of a few persons, while an ingenious arrangement of dampers and flues permits of cooking being done quite satisfactorily in the oven situated over—instead of beside—the fire.

In Fig. 25 the appearance of the stove when in use for cooking is shown, the oven door which forms the front of the false canopy being open, while Fig. 26 shows a similar stove when arranged for use as an ordinary open grate.

39. Modern forms of gas stoves may now be classed among those heating agents which supply chiefly radiant heat. Such a stove as the one shown in Fig. 27 may take the place of an open coal fire without loss of comfort and without forfeiting the advantages claimed for such an open fire from the point of view of health. The shallow character of the modern coal-burning grate is copied and the fireclay back and hollow cylindrical "gas-fuel" are both excellent radiators when heated to a sufficiently high temperature. The provision of a small flue, which should be inserted into the chimney of the ordinary fire-place—the rest of the chimney opening being left uncovered to allow the flue of the gas stove to aid ventilation by acting as an aspirator—prevents the products of combustion from polluting the air of the room. The efficiency of a well-constructed stove of this type is much greater than that of the open coal fire, and coal-gas is thus able to compete with coal in spite of its price being usually higher,

comparatively, than that of coal, while the convenience of being able to obtain quickly a hot fire, which may be entirely extinguished the moment it is no longer required, together with the freedom from the labour involved in the frequent cleaning of coal stoves, renders the gas stove of the present day a serious competitor of the older heating appliance. A further advantage which may well be urged in favour of the more common use of gas as a heating agent is the fact that in a good stove its combustion is complete, except during the first few seconds after lighting. Thus there is no unconsumed carbon, in the form of smoke, emitted by a gas stove. In large towns this matter should receive more consideration than is the case at present, since, in addition to the actual fouling caused by the presence of smoke particles in the air breathed by the inhabitants of towns, such particles form nuclei around which water particles may readily condense, thus assisting to produce the dense fogs occurring in and around some of our large towns.

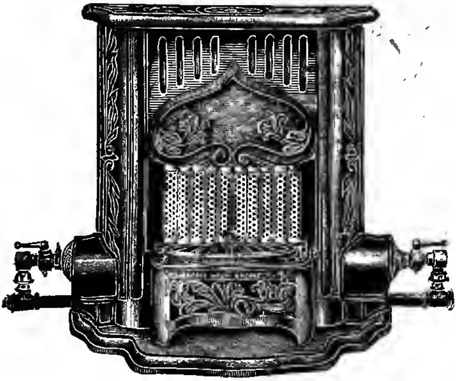

Fig. 27.

40. In the preceding paragraphs it has been claimed, on behalf of the open fire and the gas stove, that they supply radiant heat chiefly, thus copying the method of Nature. One drawback should be noted, however, which is of especial importance in the case of large rooms heated by radiant heat.

Experiment 29. Blacken the bulb of a Centigrade thermometer reading to at least 100° by covering it with a thin layer of Brunswick black. (Or, if preferred, a single layer of black paper—the strips used for fixing together lantern slides will serve—may be gummed around the bulb.) Suspend the thermometer from a retort stand in front of a bright coal fire or a gas stove at a distance of 50 cm. Allow it to remain there until the temperature registered shows no further increase. Read off this maximum temperature. Remove the thermometer to a distance of one metre and repeat the operation of waiting till the temperature has reached its maximum and again record this. Further readings may be obtained at other distances from the source of heat—say at 150 cm., 200 cm., and 300 cm. It will be found that the maxima recorded vary greatly, and that the drop in the maximum is most pronounced between the earlier readings. A curve may be plotted (see Part I, Chapter xiv) showing the relation between the maximum temperatures and the distances from the front of the stove.

### *Exercises for Student.*

1. Why is the bulb of the thermometer blackened before performing this experiment?

2. Obtain from your curve the temperatures to be expected at distances of 75 cm. and 225 cm. from the stove.

The relation between the amounts of heat which fall upon surfaces of similar area in such a case as the above may be expressed as follows:

**The quantity of heat received from a source of radiant heat by a surface of given extent varies inversely with the square of the distance of the surface from the source of heat.**

This is one of the "Laws of Inverse Squares", and the meaning of it is as follows: Suppose that the surface to be heated is placed successively at distances of 1, 2 and 3 feet from the fire, the quantities of heat falling upon it will be represented by the numbers 9, 4, and 1, if the heat received at a distance of 3 feet be taken as the unit.

From the above consideration, it may readily be inferred that, in a large room, persons near the fire may feel comfortably warm, while those at some distance from it are not conscious of receiving much benefit from the heat. In this respect, systems of heating in which convection is the chief means employed may claim an advantage over those depending mainly upon radiation for their effect. Where a room is heated by hot water or steam, the air itself is warmed and, if suitably distributed throughout the room, will cause the temperature of even those parts most distant from the pipes or radiators to be raised to a greater comparative extent than is the case with the open grate system of heating.

Experiment 30. Repeat the preceding experiment, if feasible, in a room heated only by hot-water or steam pipes. Place the thermometer at varying distances from some given part of the pipe or from the front of a radiator, and record the steady maxima of temperature as before. Plot another curve showing the relation between temperature and distance. It will be found that, in general, the differences of temperature are smaller, and that the maxima decrease less rapidly with increasing distance of the thermometer from the source of heat.

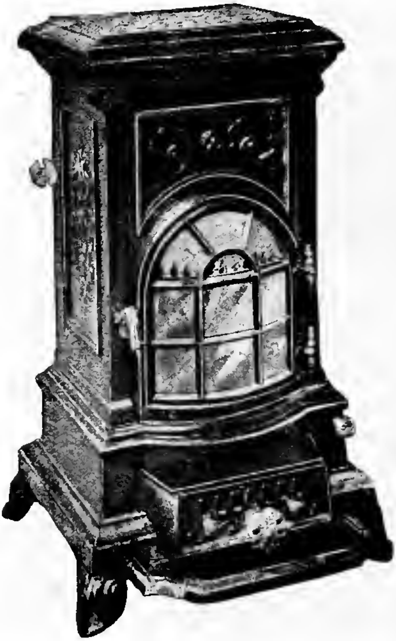

Fig. 28.

41. Several of the forms of heating appliances in use provide both radiant and convected heat. The closed stoves, of which the anthracite stove shown in Fig. 28 is a good modern example, are members of this

class. The tall cylindrical type of closed stove, more commonly found on the Continent and in America than in this country, is another. Such stoves may be efficient and healthful sources of heat, provided that they are made of good wrought iron, and are provided with a flue which carries all products of combustion into the outer air. Cast iron has been shown to be readily permeable to gases, and carbon monoxide, which may be formed by the incomplete combustion of the contents of a closed stove, may thus gain access to the air of the room. Being inodorous, its presence is not easily detected, and, on account of its poisonous properties, its occurrence in the air of a living room is greatly to be deprecated.

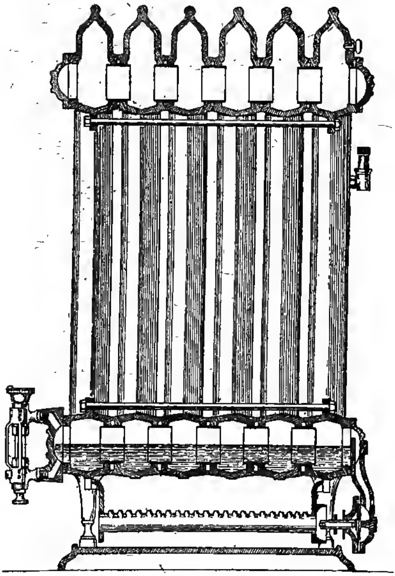

Fig. 29.

For the purpose of heating halls, corridors, staircases, stores, or other rooms not used for long periods as habitations, a convenient combination of gas and steam heating is provided by the radiators of the type of the "Main" radiator shown in section in Fig. 29. By an ingenious arrangement of an automatic valve and by-pass the pressure of the steam and hence the temperature of the radiator may be adjusted as desired. (Cp. Chapter XII, par. 132.) The fitting of a flue to carry off the products of combustion of the gas enables such a radiator to be used for heating large rooms where circumstances do not permit of the installation of the more common forms of heating appliances.

The electric radiators now on the market are usually somewhat too expensive to be installed in ordinary households with a due regard for economy. A certain amount of their heat is actually radiant, but a great portion of their value as heaters arises from the convection currents set up in the air immediately above them. Points in their favour are that they are extremely cleanly in action and that they are even less troublesome to bring into use and to extinguish than a gas stove.

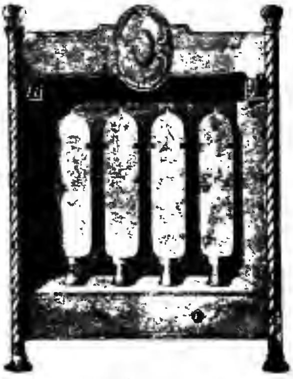

Fig. 30.

Oil stoves are not in very general use for heating purposes, although the practice of warming bedrooms with stoves similar to that shown in Fig. 31 seems to be increasing. Their use for this purpose is to be deprecated, unless the ventilation of the chamber is exceptionally good, and a first class stove, in which the combustion of the oil is rendered as complete as possible, is employed. A further improvement is to use only wicks which have been treated with chemicals, as in Stemps' process, whereby they are rendered practically incombustible and do not char, thus giving a good flame continuously with less attention than is the case with ordinary wicks.

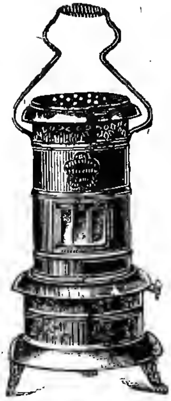

Fig. 31.

42. Systems involving provision of heat mainly by convection are commonly used in this country for large buildings and apartments only, or as a means of heating auxiliary to open fires. Fig. 32 gives in outline a diagram of a hot-water system. The furnace and boiler are situated in the basement of the building to be warmed, and the supply pipe leaves the boiler near its topmost point. Heated water rises in this pipe by the usual convection currents being set up when the furnace is lighted. In low pressure systems, similar to that figured, the hot water passes to the radiators on each floor by means of branch flow pipes as shown, till it reaches the top floor. The return pipe from the last radiator on this floor is connected with radiators in halls and corridors and from the last of these is continued to its point of entry near the bottom of the boiler. The cold-water supply pipe is shown as

connected to the main return near its entrance to the boiler, the upper end of the former pipe leading from a small feed tank which is open to the air to allow for the expansion of the water in the system when heated.

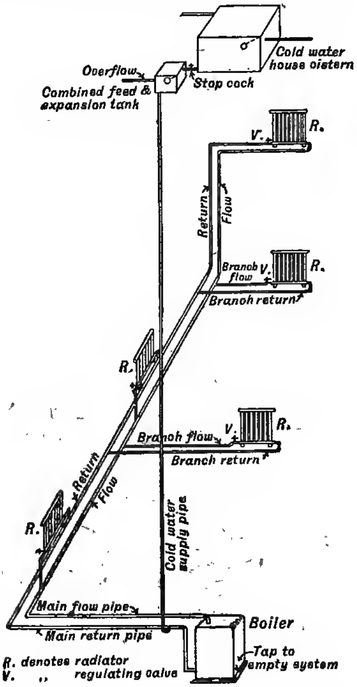

Fig. 32.

(Compare with the simple apparatus used in Experiment 73, Part I.)

The arrangement above described is known as a low pressure system, and the temperature of the water in the pipes rarely exceeds 180° F., even in the radiators nearest the source of heat. To obtain a higher temperature, the pipes must form a closed system, and it is usual to arrange a portion of the pipe as a boiler coil in the furnace. (See Fig. 33.) The course taken by the water from the boiler coil is clearly indicated in the figure. By the use of an auxiliary tank as shown, a supply of hot water for domestic purposes may be obtained. All parts of such a "high pressure" system must be strongly made, and provision must be made against possible bursting of the pipe by means of a safety valve, which permits of the escape of steam, should the temperature of the enclosed water reach a

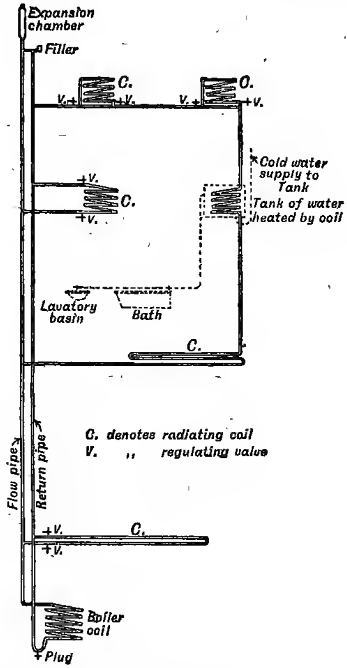

Fig. 33.

higher point than was contemplated when the installation was effected. Reference to par. 92, Part I, will explain how the temperature of the water may be raised considerably in such a system without boiling taking place. Temperatures as high as 300° F. may be attained with safety in a properly constructed high pressure system.

Heating by steam is usually carried out with "superheated" or "dry" steam, *i.e.* steam under pressure at a temperature above that of the ordinary boiling-point of water at that pressure, since, by its use, the probability of condensation of some of the steam to water in the cooler portions of the circuit is lessened. (See Chapter XII, par. 132.) It is especially suitable for factories or other large buildings where steam is used as a motive power, the waste steam which escapes from the exhaust of the main boiler being led round the building, which is thus heated economically.

The method whereby a supply of hot water for baths and other domestic purposes is obtained by using heat from the kitchen fire may well be dealt with at this point since the principle involved is the same. Fig. 34 shows diagrammatically one such system known as the "Tank and Cylinder" system. The course of the water from the "saddle" boiler—beneath the arch of which the flames and heated air from the fire pass on their way to the kitchen chimney—to the various parts of the system may be readily traced by reference to the wording on the diagram. The opening of the expansion pipe is usually situated above the main cold-water cistern. The hot-water cylinder is sometimes contained within a cupboard fitted with open shelves, so that the heat from the cylinder may be of service in airing household linen after washing.

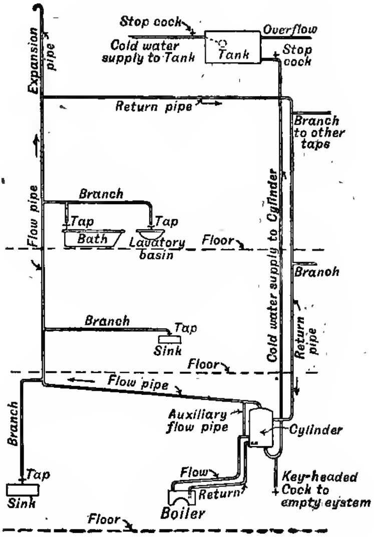

Fig. 34.

*Exercise for Student.*

How does the high specific heat of water render it of especial value as a suitable medium for conveying heat through considerable lengths of piping?

43. The special coils of pipes placed in the various apartments, although termed radiators, actually heat almost entirely by setting up convection currents in the surrounding air. They are placed most suitably beneath windows or other inlets for fresh air, the heated upward current of air being thus caused to

mingle with the cooler incoming stream, and the fresh air being distributed throughout the room without causing any unpleasant sensation of cold. It may be well to point out once more that convection systems of heating do not necessarily involve the provision of large volumes of fresh air in order to maintain their efficiency, as is the case with appliances affording radiant heat as the result of combustion. Hence the provision of proper ventilation is of greater moment in apartments heated by hot water or steam, and where such methods of heating are used in small rooms, the ventilators should be so arranged that they are not readily interfered with.

Another matter which deserves consideration is that the pipes and radiators should be kept clean and free from dust. The unpleasant smell of the heated air arising from the different parts of the system is largely due to the action of heat upon organic matter contained in the dust with which the interior of the radiators is frequently encrusted.

44. Other sources of heat are used under special circumstances. Where large manufactories abound, "water-gas" may replace coal-gas. Water-gas is produced by passing steam over red hot coke, or other form of carbonaceous fuel, and consists chiefly of carbon monoxide and hydrogen. The reaction is represented by the equation:

Carbon + hydrogen oxide = carbon monoxide + hydrogen.

"Producer-gas" is another manufacturing product which may replace coal-gas. It is formed when air is forced through thick layers of burning coke, the oxygen of the air combining with the carbon to form chiefly carbon monoxide. As we have already shown in Chapter I, this gas burns readily to the higher oxide of carbon, and is thus a valuable source of heat. Producer-gas consists of about 63 per cent nitrogen, derived from the air used in making it, the remainder being mainly carbon monoxide, mixed with a little hydrogen and carbon dioxide.

The presence of so large a proportion of carbon monoxide in these substitutes for coal-gas is a source of danger where these bodies are used for household heating purposes. The smell of ordinary coal-gas soon makes known the existence of a leak, but water-gas and producer-gas contain no odorous constituents comparable with those to which the smell of coal-gas is due. Consequently a considerable quantity of either of these gases may escape without the leakage being detected, and, as carbon monoxide is an active poison, serious effects may easily follow such leakage. The difficulty may be overcome by the addition of some odorous volatile constituent to such gases, when they are made use of for household purposes.

An interesting application of previous work upon the question of the evolution of heat during change of state (see Part I, Chapter X) is to be found in the foot-warmers used on some railways. These are filled with a hot saturated solution of sodium acetate. This liquid, while cooling, gives out heat from two sources, part of its virtue being dependent upon the heat supplied by the cooling of the water, but the major portion being derived from that set free during the crystallisation of the sodium acetate, *i.e.* evolved while the substance is changing from the liquid to the solid state. It is said that, as a heating agent, such a solution is four times as efficient as an equal bulk of water.

45. Closely connected with the subject of the heating of dwellings is that of the heating appliances necessary for the performance of the various operations of cookery. Coal, coal-gas, oil, and electricity have all

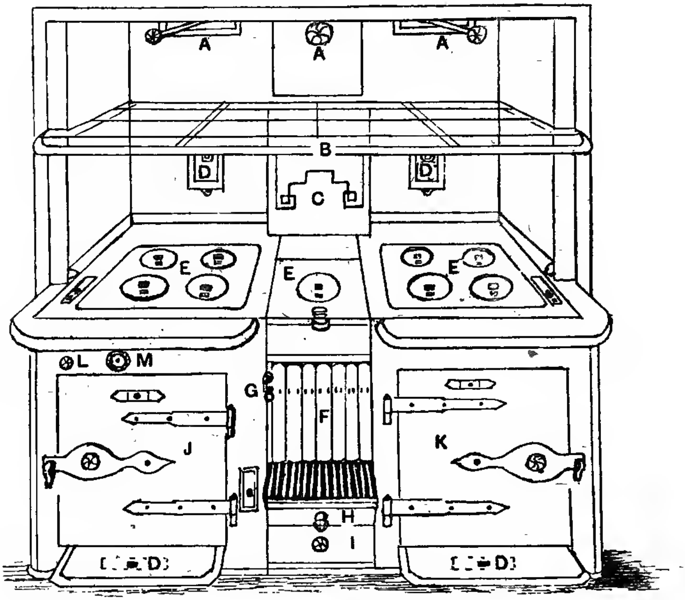

Fig. 35.

| | | | | | |
|---|---|---|---|---|---|
| *A* | Dampers | *F* | Fire Box | *K* | Meat Oven |
| *B* | Plate Rack | *G* | Movable Bottom | *L* | Regulator |
| *C* | Hood | *H* | Cinder Sifter | *M* | Regulator for Top and Bottom Heat |
| *D* | Soot Doors | *I* | Ash Box | | |
| *E* | Hot Plate | *J* | Pastry Oven | | |

been pressed into service for kitchen use. The older forms of kitchen range were generally regarded as expensive on account of the large supplies of fuel needed to obtain sufficiently high temperatures for successful cooking. In modern types of ranges, this defect has been to some measure overcome, and in such a range as that shown in Fig. 35 the cost of cooking operations is probably as low as with any other system of heating. Since such a stove is usually fitted with a boiler connected with a hot water supply for domestic use and for baths, some of the heat which would otherwise escape into the flues being thus usefully employed, it may be looked upon as an efficient adjunct to the household. The names of the various parts given beneath the figure will suffice to indicate the manner in which the heat is conserved as much as possible, in accordance with the principles already mentioned with respect to ordinary coal fires. Such a range as that shown would be too large for a small household, but smaller varieties may be obtained in which almost all the good features are preserved. For the most economical arrangement, in which the same stove may be used both as a range and as an open fire for the dining-room when not in use for cooking, see par. 38.

The disadvantages of the open coal fire are also attendant upon the use of the coal-fed kitcheners. Great care needs to be exercised in keeping the flues free from soot and considerable labour is involved in the operations of cleaning and removing waste. Hence the gas cooking-stove has become exceedingly popular of late, especially in those households where service is shared by few and economy in preparation of food is desirable. A good modern gas stove is illustrated in Fig. 36. For ready cleansing, the interior of the oven should be enamelled with a well-fired enamel, and it is better to have the hot plate treated similarly, A disadvantage of the gas stove is that the products of combustion of the gas are brought into direct contact with the food cooked in the oven. When the gas is burning properly, this is of little moment, but careless management of the contents of the oven frequently results in grease or other matter being dropped upon the burners, and, unless these be cleaned, incomplete combustion of the gas, together with destructive distillation of the waste matter, may ensue with disagreeable results.

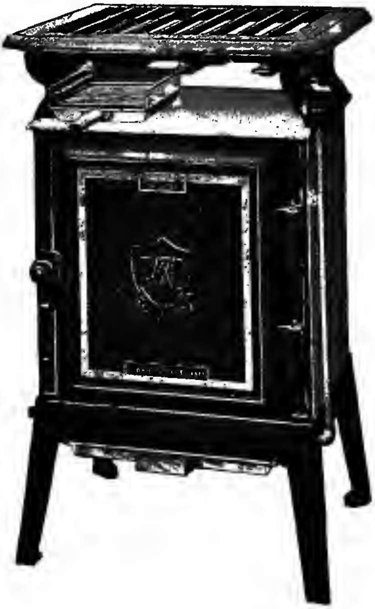

Fig. 36.

In the earlier patterns of oil stoves illuminating flames produced by the use of large flat wicks were employed as the source of heat. It is difficult to keep such a stove in a state of cleanliness and efficiency such that no smell arises and no soot is deposited in the interior of the stove. The application of the principle of the Bunsen burner, conjointly with a method of volatilising the oil before burning, has produced wickless paraffin stoves of great heating power free from the above defects. Fig. 37 is a sectional drawing of the well-known "Primus" stove. The small quantity of oil which always remains in the coils beneath the burner is gasified by burning a little methylated spirit in the cup (*b*). The vapour produced is ignited and a few strokes of the pump (*d*) cause the paraffin to be forced through the heating coil of the burner to the fine jet (*e*). Here it escapes and mixes with air, the mixture burning with a blue smokeless

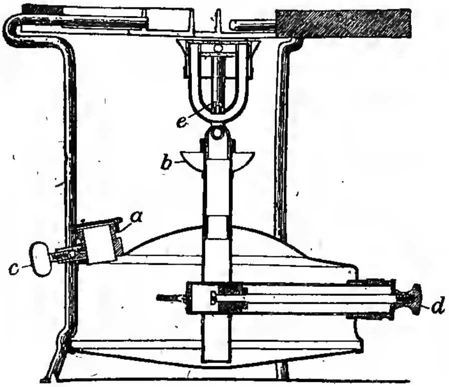

Fig. 37.

flame around the cup at the top of the burner. The heat conducted from this cup to the coil is sufficient to render the oil in the burner tubes gaseous and the stove continues to work with very little further attention. Should the flame become smaller than is needed, a few strokes of the pump will increase the supply of oil and produce a stronger flame. Special ovens may be obtained for use with such stoves and they are of undoubted service in districts where fuel is scarce or where fires are not in use during the summer months. A stove of the pattern shown in Fig. 38 will cook a dinner for five or six persons, one quart of oil being required to effect this.

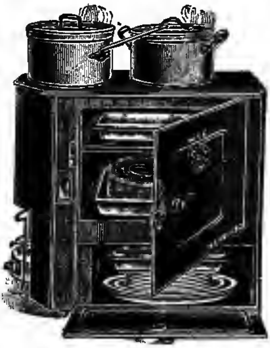

Fig. 38.

Electrical cooking appliances are now upon the market, but the prime cost of the electricity required is in general too great for their extended use. Reductions in cost are, however, being effected and the evident advantages of freedom from dirt, smell, waste, and products of combustion, together with ease of working and keeping clean, will undoubtedly lead to considerable use of this method of cooking, as soon as the cost approximates to that of cooking by the aid of coal or gas.

## QUESTIONS

1. Discuss the relative merits of open coal fires and gas stoves as suitable heating appliances for ordinary living rooms.

2. Show that conduction plays a part in each of the various systems of heating mentioned in this chapter.

3. Why is the ordinary open fire of service as an aid to ventilation?

4. Give reasons for the preference shown in most households for using coal fires rather than less troublesome heating apparatus, such as hot-water pipes or electric radiators.

5. Why are closed stoves the favourite heating appliance in Russia?

6. Convection systems of heating usually cause the air to feel dry and the skin suffers discomfort under such conditions. Suggest a possible method of remedying this defect in part.

7. For what reasons would you consider a well-fitted modern gas stove to be preferable to an ordinary coal fire in a sick room?

8. Describe any form of hot water apparatus with which you are acquainted, giving an outline sketch of the apparatus required and an account of the principles involved in its working.

9. Give a brief description of any methods you know whereby the waste heat from a coal fire may be rendered serviceable as a source of heat in other parts of the house.

10. Write a short essay upon "The relation of Ventilation to Heating".

# CHAPTER IV

## LIGHTING

46. In the preceding chapter it was mentioned that light was propagated by means of rays similar to the rays which afford the sensation of heat. Such light rays are in general produced by solid bodies in a state of "incandescence", *i.e.* raised to such a high temperature that they emit both heat and light rays. Thus in the flames of candles, coal-gas burning from the ordinary fish tail burners, and of oil lamps, the solid substance which is rendered incandescent is carbon, separated out by the partial decomposition of the materials burnt, and heated by the combustion of the remaining portion of the hydrocarbons of which those materials are composed. In the case of the Welsbach light the incandescent body is not a part of the burning substance, but is made of a material which exhibits in an especial degree the phenomenon of incandescence. The filament of an electric lamp is made to glow by the heat developed by the passage of the electric current through the material of which it is made. Systems of lighting in which the incandescent substance is not a solid are not in general use, but an example of an incandescent gas is afforded by the form of electric lamp in which mercury vapour is the illuminant.

In considering the efficiency of any source of light, attention must be paid to the conditions under which the light is used. One of the factors which is most frequently neglected is the nature of the surfaces surrounding the lamp. Thus, it is of no avail to compare the light given by any two lamps, one of which illuminates a room papered with a paper of a light green or blue tint, while the other is used in another apartment, of which the walls are covered with a deep red paper. It may be taken that, for living rooms, the best and most cheerful results are obtainable when the walls and furniture are chosen of as light a tint as possible. The human economy is readily respondent to the nature of its surroundings, and the gloom of many rooms, papered with dull-toned paper and filled with furniture of an even deeper hue, is responsible for much discomfort to those condemned to dwell in them.

Wrong position of the light is a further source of trouble and serious eyestrain may readily result from improperly placed illuminants. No unshaded light should be at a lower level than six feet, as the eye is obliged to accommodate itself each time a light below this level passes across its range. Lights, even when placed high enough, are best shaded, and this is especially applicable to the many modern lamps of high illuminating power.

47. Our next consideration will be directed to the matter of the various methods of lighting in common use, comparing those dealt with from the dual standard of economy and efficiency.

The candle is one of the earliest sources of artificial light, but has now little bearing on the question of the actual lighting of living rooms, being only made use of in rare cases for such a purpose. The difficulty experienced with the old-fashioned tallow candle of keeping the wick free from accretions of soot, which rendered snuffers an indispensable adjunct to the lighting equipment in former days, has been overcome in the present day paraffin or stearin candle by an ingenious device. The wick is composed of several strands of thread plaited together by special machinery, and one of these threads is stretched more tightly than its fellows during the process of making the wick. By this means the wick, while the candle is burning, is kept in the bent position shown in Fig. 39. The effect of this is to keep the end of the wick within the region of complete combustion (see Chapter I, Experiment 14), with the result that, as the length of wick exposed grows greater as the candle burns away, the end of the wick is consumed at an exactly equivalent rate.

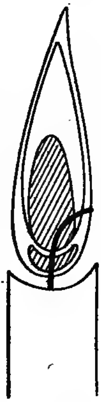

Fig. 39.

*Exercise for Student.*

Explain the formation of lumps of soot in the case of the wick of a tallow candle.

Candles are expensive if used for lighting a room, since one good gas light or electric light will give the same lighting value as from 16 to 50 candles with an expenditure which is very considerably less than the cost of such a number of candles. When to this is added the much greater convenience of the other systems of illumination, it will be seen that candle-light possesses little but sentimental attraction.

48. In districts remote from towns possessing gas or electric installations, the chief source of light is

still the oil lamp. A modern lamp, provided with central draught, with a wick chemically treated to prevent charring, and carefully constructed so that the danger arising from its careless handling is reduced to a minimum, is inexpensive and at the same time a very efficient illuminant. The danger arising from the use of "low flash" oil, *i.e.* oil containing constituents of low boiling-point, which readily evaporate and form an explosive mixture with air, has been somewhat modified by the demand for petrol, naphtha, and benzoline, which consist of the more volatile products of the destructive distillation of crude petroleum. Their more complete extraction being now a matter of commercial importance, it will be found that the cheaper varieties of paraffin oil on the market are almost as safe in use as the more highly priced samples.

Experiment 31. Pour a *few* drops of petrol into a porcelain basin. Bring a lighted taper near the surface of the liquid. The immediate production of a flame is evidence of the presence of much inflammable vapour. (The "flash point" of a liquid is the temperature to which it must be raised in order that combustion of its vapour may take place when a small flame is brought near its surface.)

Into another dish pour a small quantity of paraffin oil. Bring a lighted taper near the surface of the liquid. It will be found that it does not ignite, and, on passing the flame of the taper into the paraffin, the flame may be extinguished.

### *Exercise for Student.*

What inference would you draw from the behaviour of the paraffin, should the above treatment result in its ignition?

Place the dish containing the liquid upon the surface of water in a water-bath. Gently warm the bath with a small Bunsen flame, and test the inflammability of the contents of the dish from time to time with a lighted taper. A point will at length be found at which the paraffin begins to burn and will continue burning after ignition.

The above tests may be repeated with *small quantities* of mixtures of petrol and paraffin in the proportions of 1 : 10, 1 : 5, and 1 : 3.

The following experiments show that a substance does not burn below a certain temperature—termed its "ignition point"—and indicates the reason for using wire gauze and perforated metal stampings in the construction of burners for oil and gas lamps.

EXPERIMENT 32. Place a square of clean wire gauze upon a tripod stand over a large plate. Pour about 3 c.c. of methylated spirit into a small porcelain dish and ignite it. Pour the contents of the dish, while still burning, through the gauze. It will be found that the portion of spirit remaining on top of the gauze continues to burn, but that the spirit which is received by the plate is no longer alight.

The explanation is that the gauze is a very good conductor of heat, and cools the spirit passing through it so that the former never reaches a temperature as high as its ignition point, although the upper surface of the gauze is in actual contact with the burning liquid.

EXPERIMENT 33. Hold a piece of clean wire gauze, of which the mesh is not very coarse, over the flame of a good Bunsen burner, and depress the gauze slowly until it rests upon the top of the burner. Note the behaviour of the flame.

Turn out the gas and place the gauze above the top of the burner at a distance of about one inch. Turn on the gas and bring a lighted taper near the upper surface of the gauze. The gas ignites, but the flame remains on top of the gauze and does not pass through to the inflammable mixture of air and gas which exists in the space between the gauze and the top of the burner. Depress the gauze till it touches the top of the burner and again raise it. The gas beneath is not ignited even by this operation. Raise the gauze slowly and note the change in the flame. By raising it sufficiently, the flame may be extinguished.

*Exercise for Student.*

Explain the behaviour of the flame in the above experiment.

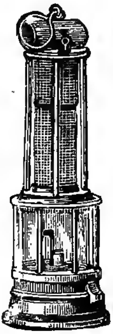

Fig. 40.

An interesting application of the conducting properties of wire gauze is afforded by the miner's lamp. Fig. 40 shows a modern form of such a lamp—the Marsaut lamp. The lower part of the lamp around the flame is of glass, while the supply of air necessary for the continuous burning of the flame is obliged to pass through the cylinder of fine wire gauze which is fixed above the burner. A mixture of air and marsh gas—the combustible gas sometimes found in coal-mines, termed by the miners "fire-damp"—may surround such a lamp, and, although such a mixture is explosive, the exterior surface of the gauze envelope rarely reaches a sufficiently high temperature to ignite the mixture and thus cause an explosion. The marsh gas may be seen burning within the lamp, but, unless a strong draught or other means causes the flame of the burning gas to make the gauze red hot, the miner is safe from harm.

49. In most households coal-gas provides the illumination required for evening work. The older forms of burner were of two main types known as the "batswing" and "fishtail" respectively. The batswing burner consists of a brass tube with a steatite top, the latter being divided by a transverse slit, through which the gas issues. The form of the slit determines the shape of the flame obtained. The fishtail burner is of similar construction, differing only in that the steatite is pierced with two holes directed towards one another instead of being provided with a slit.

EXPERIMENT 34. Draw out a piece of glass tubing of about ¼″ bore as described in Experiment 46, Part I. Cut off the drawn-out portion so as to form two jets of as nearly as possible the same bore. Fix these by means of clamps so that they are directed toward one another as shown in Fig. 41. Attach the lower ends of the tubes to two gas jets on the working bench by rubber tubing. Turn on the gas and light it at each of the glass jets. By suitably manipulating the positions of the tubes, the flames may be made to impinge upon one another. It will be found that they spread out at the place of meeting into a flat flame which is in a plane at right angles to that containing the directions of the tubes. By changing the angles and positions of the jets with regard to each other, try to find the arrangement which gives the best illuminating flame. Measure the angle between the directions of the tubes when the most efficient position has been determined.

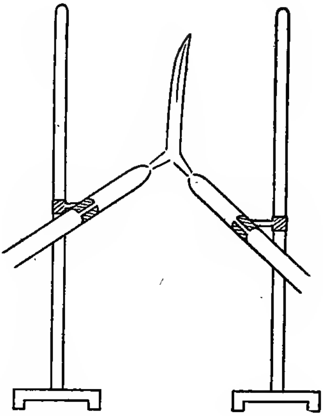

Fig. 41.

It may be necessary to adjust the gas supply to each jet and to alter slightly the size of one or other of the jets in order to obtain a good representation of an ordinary fishtail flame.

As already shown in Chapter I, the source of the light in such burners as those described is the carbon set free during the decomposition of the hydrocarbons of the coal-gas by heat, and unless the sample of coal-gas used is comparatively rich in those compounds which contain a relatively high proportion of carbon, the light afforded is poor when the quantity of gas consumed is taken into account.

EXPERIMENT 35. Fit up the apparatus shown in Fig. 42. The lower end of the bent T-piece is connected to the gas supply, and the gas turned on. A light is applied to each of the new fishtail burners attached to the tops of the side-tubes, and the flames produced examined with regard to their luminosity. Arrange that the two flames shall be as nearly as possible of the same size and illuminating power by adjusting the supply to each by means of the three-way tap at the junction of the T-piece. Now turn off the gas at the main tap, without disturbing the arrangement of the three-way tap. Remove one of the upper corks and insert a wad of cotton-wool which fits the large side-tube loosely. Drop on the cotton-wool a little benzene. Replace the burner and light both flames again. It will now be easily seen that the burner receiving a supply of benzene vapour as well as coal-gas gives a much better light than the other. Benzene is a hydrocarbon containing over 90 per cent of carbon. The above experiment illustrates the important part played by the presence of such bodies in coal-gas in determining its value as an illuminant.

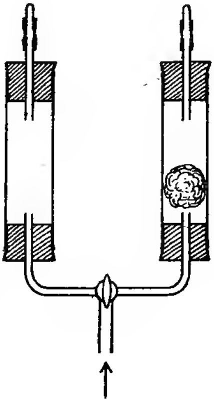

Fig. 42.

A fishtail burner which consumes from four to five cubic feet of gas per hour will only give a light of about 14 to 16 candle power under ordinary conditions. (In this country the standard candle indicated when speaking of "candle power" is a sperm candle of special construction consuming 120 grains—about 7·79 grams—of sperm per hour.) Many devices have been brought forward to increase the illuminating power of coal-gas, among them being the addition of hydrocarbons rich in carbon to the gas before it is consumed (compare par. 5, p. 9), but of these by far the most successful is the incandescent mantle for which we are indebted to the researches of Auer von Welsbach and his co-workers. The property of incandescence is not possessed in an equal degree by all solid bodies, and the materials of which the incandescent gas-mantle is constructed are especially endowed with the capacity for glowing brightly when heated to a high temperature. The substances made use of are two rare oxides, the oxides of cerium and thorium. To make a suitable incandescent medium, a mantle is woven of special cotton fibre and is then dipped into a solution of the nitrates of cerium and thorium, mixed in proper proportions—the most efficacious being a mixture which will provide a mantle consisting of about 99 per cent thorium oxide and one per cent cerium oxide after the further treatment to be described. The cotton is allowed to dry and is then ignited. The fabric burns away and the flimsy network of mixed oxides resulting is hardened and shaped in a blowpipe flame. The fragile replica of the original is then rendered capable of transport by dipping it into collodion, which is allowed to dry, forming the shiny coating seen on new mantles. When the mantle is brought into use, this coating is first burnt off, the mantle having been previously placed in position over the burner.

The type of burner used in conjunction with the Welsbach mantle is a Bunsen, provided with a cover of gauze to spread the flame and to allow of a large supply of air being made use of with less danger of the flame striking back. The best results are only obtainable when a suitable burner is used, in which provision is made for the regulation of the air supply as well as that of the gas. A good light may be procured if attention be paid to securing a flame of such dimensions that it just fills the interior of the mantle, the material of which is then in contact with the region of complete combustion, and is thereby rendered uniformly incandescent. Cautious adjustment of both gas and air supplies is necessary if the brightest light obtainable is desired with a given burner and mantle. Usually the full pressure of gas is not required and a better effect is gained by turning off a portion of the gas.

EXPERIMENT 36. Test the above statements by finding the conditions under which any Welsbach burner available gives its brightest light. Try the effect of (*a*) using the full supplies of air and gas; (*b*) leaving the gas full on, and reducing the air supply by partially closing the holes at the base of the burner; (*c*) using the air holes opened to their widest extent and turning the gas off gradually.

It should be noted that a distinct advantage possessed by the Welsbach system over that involving the use of fishtail or batswing burners is that it permits the use of a gas containing but a small proportion of hydrocarbons rich in carbon, the brightness of the flame being in no way dependent upon the presence of these bodies. In fact, their presence is rather to be deprecated than encouraged.

Many attempts have been made to adapt the incandescent mantle for use with oil lamps, but partial success only has been achieved at present, all the lamps now on sale requiring greater care and attention than the average householder or his employees are usually prepared to give to them.

50. To obtain a rough comparison between the lighting values of a fishtail burner and an incandescent

burner, it will be of service to describe briefly the method of measuring the quantity of gas supplied. A gas meter is a mechanical contrivance designed to this end. By means of an ingenious system of levers, the gas, in its passage through the bellows of the meter to the house supply, is made to register the volume passing upon a number of small dials situated upon the front of the apparatus. A view of the dials of a

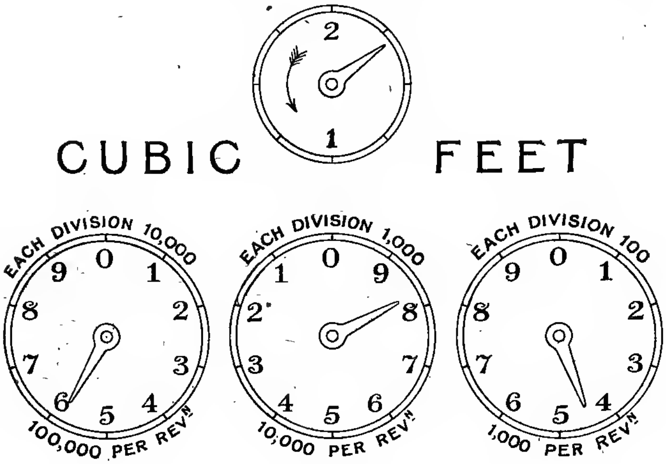

Fig. 43.

typical "dry" gas-meter is shown in Fig. 43. The gas company makes a charge for each thousand feet of gas consumed, as shown by the reading of the meter, the amount of the bill being calculated to the nearest hundred cubic feet. The right-hand dial indicates the figure in the hundreds' place, the middle one that in the thousands', while that on the left registers tens of thousands. Thus the reading of the dials as figured is 58,400 cubic feet. It will be noted that this reading is obtained by observing the figure last passed by the end of each pointer in its course round the dial. Periodical inspection of the meter by the officials of the company enables the amount to be charged to be correctly estimated for any given period, assuming the meter to be in good working order.

For our purposes, however, the small dial placed above the others is of more especial interest. This usually registers two cubic feet per revolution. That is to say, every time the hand passes once round the dial, two cubic feet of gas pass through the meter.

Experiment 37. Arrange that no other gas shall be burnt during the experiment than that used by the burner tested. Set up a fishtail burner and adjust the supply of gas so that the flame produced is the brightest possible. Note the time at which the hand of the small dial on the meter is exactly vertical, and allow the burner to continue burning until the hand reaches the mark indicating one cubic foot. The interval of time that has elapsed represents the time required for one cubic foot of gas to be consumed by the special burner used. A simple calculation will show how many cubic feet must be supplied to such a burner per hour.

Replace the fishtail by an incandescent burner provided with a mantle. Adjust the gas and air supplies till the brightest flame is obtained as before. Note the time taken for one cubic foot to be consumed and find how many cubic feet are used per hour.

The results obtained in the above experiment will generally show that the Welsbach light consumes no more—and usually less—gas than the fishtail, while giving a much more brilliant illumination. Measurement of the intensity of the light afforded by these two sources by suitable means will show that the incandescent light is about four times as economical as the ordinary flame, equal illuminations being compared in the two cases.

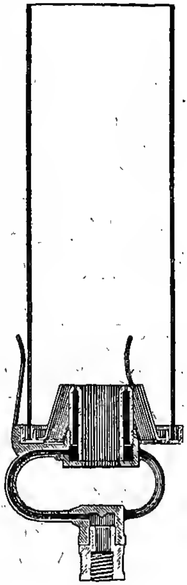

Fig. 44.

51. The Argand burner, illustrated in Fig. 44, is also much more efficient than the flat flame burner. In this type, a higher temperature, and hence brighter incandescence, is produced by the regulation of the air-currents around the flame by the chimney. The gas escapes through a series of small holes situated around the ring of steatite at the top of the burner, and the air-current which is set up by convection passes upward from the base of the burner and is evenly distributed around and within the flame by the perforations in the metal base of the chimney-holder.

Experiment 38. Light an Argand burner with the chimney off. Note the nature of the flame, more especially with regard to its steadiness, freedom from smoke, and luminosity. Place the chimney in position, and again examine the flame, paying attention to the same points as before.

The value of the chimney is well demonstrated by the comparison of the observations made in the above experiment. A similar test performed with an oil lamp will afford similar results.

52. A valuable modern application of the Welsbach principle to the lighting of small communities or country houses is to be found in the petrol-air gas system. In this, a mixture of petrol vapour and air of varying proportions, ranging from one and a half to six per cent of vapour in different systems, is the heating agent which is burnt in burners of almost similar construction to those used for incandescent coal-gas, and raises to incandescence a mantle resembling the Welsbach mantle. The plant may be very small, producing only sufficient of the combustible mixture to supply a few burners, or it may be large enough to illuminate a factory or small town. The cost of the light is most reasonable, and the danger attending its use is not greater, with average care, than is the case with ordinary coal-gas installations.

53. Acetylene, one of the constituents of coal-gas from which much of the brilliancy of the light of the latter is derived, is occasionally used as an illuminant. The light afforded is very bright and is said to be especially healthful since, in the nature of the rays emitted, it resembles daylight more nearly than any other artificial source of light. The gas is made from calcium carbide—a compound of calcium, the metal present in lime and chalk, with carbon—by acting upon the carbide with water. The reaction which takes place may be represented by the equation:

$$\left.\begin{array}{c}\text{Calcium carbide}\\+\\\text{hydrogen oxide}\end{array}\right\}=\left\{\begin{array}{c}\text{calcium hydroxide}\\+\\\text{acetylene.}\end{array}\right.$$

Experiment 39. Half fill a small trough with water. Drop a small piece of calcium carbide into the water. A rapid evolution of gas is at once produced, and it may be readily recognised by its peculiar smell. To show its great luminosity, a small inverted funnel may be placed over the lump of carbide, so that the top of the funnel projects just above the surface of the water. The gas may then be lit as it issues from the end of the funnel. A bright but very smoky flame results. (The smokiness is prevented, when the gas is made use of as an illuminant, by the use of burners of the fishtail type, specially constructed for the purpose.)

A serious drawback to the general use of acetylene for purposes of household lighting is the large quantity of slaked lime, saturated with the unpleasant smell of the gas, which has to be removed from the lamps, or other form of apparatus, at frequent intervals.

54. The great development of electrical industries in recent years has resulted in the production of many efficient types of electric light. Of these, the incandescent carbon filament lamp was the first to receive much attention as a household illuminant. Its prime cost was comparatively low, but the price of electricity was sufficiently high in comparison with that of coal-gas to prevent its general adoption. The invention of the metallic filament lamp gave an impetus to the use of electricity, since, although the prices charged for the lamps were considerably greater than those of carbon lamps, the quantity of electricity consumed for a given amount of illumination was much decreased by their use. The metals commonly used in making the filaments, like those of which the oxides form the material of the Welsbach mantle, are all comparatively rare and include, among others, tungsten, titanium, tantalum and osmium.

The incandescent filament of an electric lamp provides an example of a light-giving substance which is not burning. The carbon or other material of which the filament is composed will burn quite readily if raised to a high temperature in air. It is prevented from doing so in the lamp by first exhausting the interior of the latter almost entirely by means of a powerful pump. The passage of the electric current through thin wires produces heat, the quantity produced being greater the thinner the wire. By careful adjustment of the length and thickness of the wire in the lamp, it is possible to produce a light of suitable intensity when used with a given supply of electricity. Each supply is said to be at a pressure of so many volts. Lamps constructed for use with a low pressure—say 50 volts—cannot be used with higher voltages, since the temperature to which the filament is raised when the lamp is thus used is sufficient to destroy it in a very short time. Conversely, lamps suitable for use at high voltages are of no service at lower pressures, the temperature attained being too low to produce light of sufficient brightness. Hence it is of importance to the consumer to obtain lamps suited to the voltage as supplied to his house.

That the materials of which filaments are constructed are combustible is readily observed whenever a lamp is broken while alight. The filament is usually found to be almost entirely consumed when this occurs.

A type of filament lamp has been recently placed on the market, in which the globe contains nitrogen instead of being rendered vacuous, and this lamp gives a light of great brilliancy. At present the lamps made are chiefly suitable for public lighting on account of their high candle power, but the adaptation of this form of lighting to household use is in progress. The quantity of electricity consumed for a given illumination is much lower than with the other systems previously mentioned.

Of different type are the arc lamps frequently used for street lighting and for large rooms. In these the current is conveyed to two rods of gas-carbon—the hard deposit which forms on the interior of the retorts during the process of coal-gas manufacture—and the interruption of the contact of these two rods by a small air-gap results in the production of a light of great brilliancy.

55. The quantity of electrical energy supplied for the purposes of lighting or heating is measured by means of a meter, as in the case of coal-gas. The unit of measurement is known as the "B. T. U." or Board of Trade Unit. Electricity is sold at prices which vary from less than a penny a unit, when the supply is used for heating purposes, to 8*d.* per unit for lighting, the latter amount being the maximum price per unit permitted by law. The average price for lighting purposes may be taken as 4*d.* per unit. A typical meter is shown in Fig. 45. The numbers which appear in the small round spaces are to be read from left to right and give the total number of units that has been recorded by the meter up to the time of reading. Thus the reading of the meter as illustrated is 2482 units. Periodical inspection of the meter provides the company supplying the electricity with the information needed to assess the charge to be made on the consumer. Some meters are provided with a small dial resembling the upper dial on the gas-meter. This is of service when testing the efficiency of an electric heating

apparatus or lamp. One revolution of the hand round the dial indicates that one unit has been used, and each of the divisions represents one-tenth unit. Thus, if we wish to test the claim of the makers that a certain 50 candle power electric lamp consumes only one-twentieth unit per hour, all that is necessary is to see that all other lights are switched off, and then to burn the given lamp alone for a known time, say,

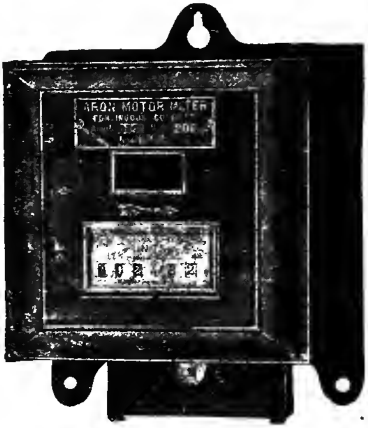

Fig. 45.

five hours, and to note the change in the register of the small dial.

56. There are several other kinds of electric lamp on the market, but a description of them is beyond the scope of our book. It may be well, however, before concluding this chapter, to state briefly the present condition of the argument with respect to the comparative hygienic values of gas and electric light. When the latter form of indoor lighting was

first introduced, one of the chief claims made on its behalf was that the use of the enclosed filament lamp would tend to improve the respirability of the air in rooms lit by this lamp. The basis of this argument is, that, since no combustion occurs in the filament lamp, there are no noxious products of combustion evolved whereby the air may be polluted. The advocates of gas-lighting point out that this is a doubtful advantage, for the heating effect produced by an electric lamp is much less than that of an incandescent gas-burner, and consequently the convection currents set up by the electric lamp are of lesser account than those due to gas-lights. Thus one of the points—air-movement—specially desirable, according to modern views of ventilation, is not dealt with in as satisfactory a fashion where electricity provides the light as when incandescent gas is the illuminant. Moreover, the strong uprush of air through the chimney of the incandescent burner carries with it a considerable quantity of dust particles and organic matters which are burnt during their passage, and thus the latter are rendered innocuous. The dark patch upon the ceiling immediately over a Welsbach burner is caused by the continual bombardment of the plaster by a stream of charred particles of this nature, and is not evidence that the flame produces smoke. No considerable destruction of organic matter occurs where electric light is used. This sterilising effect is an undoubted advantage and the current of heated air, reaching the ceiling at a temperature considerably higher than that arising from an electric lamp, diffuses through the porous material of the ceiling more rapidly, hence producing a greater inrush of air at some other part of the room. Comparative tests, carried out with great thoroughness, have been made of the relative virtues of the two sources of light, and the general conclusion derived from the results of these has been that the choice between the two methods of lighting is a matter which may well be considered quite apart from hygienic grounds, *i.e.* the consumer can suit his convenience and pocket without serious detriment to his health.

## QUESTIONS

1. How do you explain the production of light in the case of each of the following appliances: (*a*) a paraffin lamp; (*b*) a fishtail gas-burner; (*c*) an incandescent burner?

2. Suggest a rough method of discovering whether it would be more economical to light a room with oil lamps burning paraffin at 8*d.* a gallon, or with Welsbach lights supplied with coal-gas at 2*s.* 6*d.* per 1000 cubic feet.

3. Compare the relative merits of gas and electric lighting, paying special attention to the following points: (*a*) convenience; (*b*) cleanliness; (*c*) cost; (*d*) healthfulness.

4. What experiments would you perform to determine which of two samples of paraffin oil possessed the higher flash-point?

5. What is meant by the ignition point of a vapour? Why is wire gauze used in the construction of some burners?

6. Describe the principle of construction of the fishtail gas-burner.

7. Of what is an incandescent gas mantle made? What is the special function of the mantle?

8. On March 28th the reading of a gas-meter gave the figures 4, 7, 3. On July 1st the same meter showed 5, 0, 2, as the figures on the three main dials from left to right. Calculate the amount of the bill, supposing the price of gas to be 2*s.* 8*d.* per 1000 cubic feet.

9. Discuss the value of acetylene as an illuminant. How is this gas produced?

10. Which system of lighting a room would be the cheaper: (*a*) to use two 50 candle power incandescent gas-burners, each consuming 4 cubic feet of gas per hour, with gas at 3*s.* 4*d.* per 1000 cubic feet, or (*b*) to use three metallic filament lamps, each of 32 candle power and consuming $\frac{1}{25}$ unit per hour, at 3*d.* per unit?

# CHAPTER V

## WATER IN THE HOUSEHOLD

57. The physical and chemical properties of water have already received attention in Part I of this work, and our business in this chapter is largely the application and extension of the information previously afforded to the question of the suitability or otherwise of a given water for domestic purposes, *i.e.* whether it is fit for drinking and for use as a cleansing agent.

In Experiment 119, Part I, it was shown that ordinary tap-water contains dissolved solid matter, and is hence not pure water. All naturally occurring samples of water are contaminated in this way, since water is the most general solvent known, and there are few substances which will not dissolve in it to some extent. Even rain-water, the purest natural water, contains dissolved gases derived from the atmosphere, together with small quantities of solid matter obtained from the dust with which it has come in contact during its fall. Many of the substances present in natural waters are of importance on account of their effect upon the utility of the water for domestic purposes.

The solid matters dissolved in natural waters may be divided into groups, according to their origin. Thus the bicarbonates and sulphates of calcium and magnesium, their chlorides and that of sodium, are of mineral origin, being derived from the various bodies with which the water has been brought in contact during its passage through or over the soil. On the other hand, the ammonium compounds, the nitrites, the nitrates, and phosphates occasionally contained in samples of natural water, are of organic origin. They are present as a result of the contamination of the water by products arising from the decay of animal or vegetable matter in the soil through which the water has percolated. In addition to the above-mentioned substances, there are others which may be found on occasion in water supplied for household consumption, these latter having been introduced by artificial means, *e.g.* lead from water-pipes is slightly soluble in certain kinds of water. Of the substances mentioned, all affect the desirability of the water for drinking purposes, with the exception of the salts of calcium and magnesium which head the list. The main effect of these latter salts is to cause the water to be less suitable as a cleansing agent.

58. Water containing salts of calcium and magnesium in any quantity is said to be "hard". The sulphates of these metals are directly dissolved from the earth by water, even when the solvent is quite pure. The solubility of calcium sulphate is practically unaffected by boiling the water, the salt being almost equally soluble in cold and hot water. Magnesium sulphate follows the ordinary law in this respect, being more readily soluble in hot than in cold water. (See

Part I, par. 187.) When water containing these dissolved salts is boiled, the salts remain in solution, unless the greater portion of the water is boiled away. The hardness due to the sulphates is in consequence not affected by boiling, and water which contains them in any quantity is termed "permanently" hard.

The case of the bicarbonates of calcium and magnesium is of somewhat different character. These substances do not occur in Nature in the solid state, but are produced by the solvent action of water, already containing dissolved carbonic acid, upon the naturally occurring carbonates. Chalk, limestone, and marble are forms of calcium carbonate, while dolomite is a mixed carbonate of both calcium and magnesium. The bicarbonates are unstable bodies, being readily decomposed by heat.

EXPERIMENT 40. Pass a steady stream of carbon dioxide from a Kipp's generator (see Chapter I, Experiment 6) through some distilled water for several minutes. In this way a weak solution of carbonic acid—hydrogen carbonate—may be obtained. In Nature a similar formation of the acid occurs. Rain corresponds to our distilled water. While falling through the air it dissolves a small amount of carbon dioxide, and the solution thus produced is rendered stronger during the passage of the water through the soil, where it comes in contact with the ground air (see Chapter II) which is especially rich in carbon dioxide, derived from the processes of decay which are continually taking place in the soil.

Through a quantity of lime-water, equal in bulk to the distilled water previously used, pass a stream of carbon dioxide until considerable turbidity has been caused, due to the formation of insoluble calcium carbonate by the combination of the lime in the lime-water with the carbon dioxide. This calcium carbonate may thus represent chalk or limestone. The rain-water, after percolating through the soil, frequently reaches a layer of chalk or limestone, and we may reproduce the reaction which occurs by mixing the two liquids we have already prepared. On doing this, the turbidity of the second liquid disappears, *i.e.* the calcium carbonate dissolves in the solution of carbonic acid. A similar phenomenon occurs in Nature, and, after the water has soaked through chalk or other form of naturally occurring calcium carbonate, it contains a certain amount of the bicarbonate of calcium in solution.

We may represent the reactions which we have just studied by the following equations:

$$\left.\begin{array}{c}\text{Hydrogen oxide}\\ +\\ \text{carbon dioxide}\end{array}\right\} = \text{hydrogen carbonate.}$$

$$\left.\begin{array}{c}\text{Hydrogen carbonate}\\ +\\ \text{calcium carbonate}\end{array}\right\} = \text{calcium bicarbonate.}$$

The liquid we have prepared corresponds to water which has passed through a stratum of chalk. In Nature, such water issues at a later period as a spring, and the water may then either be used directly, or may be treated before use. We may now show how such spring water behaves when boiled. Boil the liquid already prepared and watch its behaviour while being heated. At an early stage of the heating, small bubbles will arise in considerable numbers. These are bubbles of carbon dioxide, produced by the decomposition of the carbonic acid present in excess in the water. (Similar streams of small bubbles may be observed while many samples of ordinary tap-water are being heated, and the noise produced in a kettle in which water is being heated, commonly termed "singing", is caused by the setting free of such bubbles in large numbers from the water.) Later, the appearance of steam is heralded by the formation of much larger bubbles, and the water soon becomes turbid. Continue the boiling for a few minutes, and then allow the liquid to stand. A white deposit will then be remarked at the bottom of the vessel, and its interior will be covered with a thin coating of whitish substance. Carefully pour off a sample of the liquid, so as not to disturb the precipitate, into another clean glass vessel. It will be seen that the water is quite clear, and further boiling will fail to produce any appreciable turbidity. Pour off the remaining liquid from the vessel in which the original water was boiled, and try to remove the deposit from the interior of the vessel by repeated rinsing with distilled water. It will be found that such treatment has practically no effect. Now drop two or three drops of dilute hydrochloric acid into the vessel. The immediate solution of the deposit results, and, if carefully watched, the production of many small bubbles will show that the substance resembles chalk in its behaviour towards acids.

The changes taking place when water of this character is heated are the reverse of those already given and represented in the equations, p. 108. Hydrogen carbonate is destroyed by heat, and calcium bicarbonate suffers a similar decomposition. The equations for these reactions may be written:

$$\text{Hydrogen carbonate} = \left\{\begin{array}{l}\text{hydrogen oxide}\\ \qquad\quad +\\ \text{carbon dioxide.}\end{array}\right.$$

$$\text{Calcium bicarbonate} = \left\{\begin{array}{l}\text{calcium carbonate}\\ \qquad\quad +\\ \text{hydrogen oxide} + \text{carbon dioxide.}\end{array}\right.$$

From the above experiment, it may readily be seen that the boiling of waters containing calcium bicarbonate in solution results in the decomposition of the bicarbonate and the deposition of the insoluble carbonate thus produced. The hardness due to such dissolved bicarbonate is in consequence destroyed by boiling. Hence hardness of this character has received the name of "temporary" hardness.

The boiling of all waters containing dissolved bicarbonate of calcium gives precisely similar results to that obtained with our artificially produced sample. The deposit is not so pronounced (see Experiment 121, Part I), but the repeated boiling of successive quantities of such water in a kettle or boiler causes the formation of overlying layers of deposit, which in time attain to a sensible thickness, and are known as "fur". This substance consists essentially of calcium carbonate, its pale brown colour being the result of the presence of traces of iron.

Observations of similar character may be obtained if magnesium carbonate be dissolved in carbonic acid, and the solution be then boiled. The deposit then formed is, of course, magnesium carbonate.

The deposition of fur is of importance in household affairs, since it is an extremely bad conductor of heat.

A well-furred kettle requires longer heating before the water it contains is brought to the boiling point than does a clean kettle. Waste of fuel is thereby caused. Further, the collection of a thick deposit of fur—then known as "boiler scale"—upon the interior of a boiler may give rise to serious trouble. Sudden contraction of the scale by the introduction of cold water may result in a cracking of the scale. Water may thus be suddenly brought into contact with the overheated metal of the boiler, and may be caused to boil with explosive violence. Where no scale exists, the material of the boiler cannot be overheated as long as water is contained within the boiler.

59. Simple tests by which the presence of some of the commoner impurities likely to occur in natural waters may be detected should next be performed. Samples of tap and distilled water should be tested side by side in each case.

To show that calcium is present in a given sample of water, the following test may be performed:

EXPERIMENT 41. Add to a small quantity of the water a few drops of ammonia solution. This should be added in just sufficient quantity to render the water alkaline to litmus. Next add about 1 c.c. of ammonium oxalate solution. Shake well. The production of a precipitate or of turbidity, due to the formation of insoluble calcium oxalate, may be taken as evidence of the presence of calcium in the water tested.

EXPERIMENT 42. To test for the presence of sulphates, add a few drops of hydrochloric acid to a little of the water, and then add 1 c.c. of barium chloride solution. A precipitate—barium sulphate—indicates that sulphates are contained in solution in the water.

Experiment 43. The presence of bicarbonates is most readily demonstrated by boiling the sample of water, as already indicated. A further test may give a definite result, if the quantity of bicarbonate present is of fair amount. Add to a sample of the water an equal bulk of saturated lime-water. The production of turbidity after the mixture has stood for a few minutes may be considered evidence of the presence of bicarbonates.

The equations involved in the above tests are:

$$\left.\begin{array}{c}\text{Calcium sulphate}\\+\\\text{ammonium oxalate}\end{array}\right\}=\left\{\begin{array}{c}\text{calcium oxalate}\\+\\\text{ammonium sulphate.}\end{array}\right.$$

$$\left.\begin{array}{c}\text{Calcium sulphate}\\+\\\text{barium chloride}\end{array}\right\}=\left\{\begin{array}{c}\text{barium sulphate}\\+\\\text{calcium chloride.}\end{array}\right.$$

$$\left.\begin{array}{c}\text{Calcium bicarbonate}\\+\\\text{calcium hydroxide}\end{array}\right\}=\left\{\begin{array}{c}\text{calcium carbonate}\\+\\\text{hydrogen oxide.}\end{array}\right.$$

### *Exercise for Student.*

Obtain some fur from a kettle, and endeavour to show that it contains calcium and a carbonate.

60. The question of the water supply of a household being hard or soft is of primary importance from the point of view of economy. Hard water is the cause of much wastage of soap, and we will next examine the nature of its reaction with that material.

Experiment 44. Make a solution of soap as follows: Cut some Castile soap into thin shavings and weight out 10 g. of the shavings. To 400 c.c. of absolute alcohol add 600 c.c. of distilled water, and completely dissolve the soap shavings in this mixture. Fill a clean burette to the zero mark with the soap solution. Clean two flasks—or, better, small bottles provided with glass stoppers—and into one measure out with a pipette 50 c.c. of freshly distilled water and into the other an equal quantity of tap-water, or any other water requiring examination. Place the bottle containing the distilled water beneath the tap of the burette, and allow 1 c.c. of the soap solution to run into the bottle. Securely stopper the bottle and shake it vigorously for about 20 seconds. This will probably result in the formation of a lather which persists after the bottle has been allowed to remain undisturbed for two minutes. If this is not the case, add another cubic centimetre of the soap solution, and repeat the shaking and standing. The amount of soap solution needed to obtain a so-called "permanent" lather will be found to be small.

Repeat the above operations, adding 1 c.c. of soap solution at a time, with 50 c.c. of the sample of water to be tested, using as nearly as can be judged the same amount of vigour in shaking. Usually the volume of solution which must be added before a permanent lather is produced is very considerably greater than that required for the distilled water. When the lather remains unbroken for two minutes, note the volume of solution used. By subtracting the volume required by the distilled water, the difference, which represents wasted soap, may be found. Check the result by performing a second titration. (A titration means a finding of strength, or quality, from Fr. *titre*, a standard.)

To discover whether the hardness of the water is temporary or permanent, or is partly of each kind, boil 50 c.c. of the water, allowing it to remain boiling for at least five minutes. Cool to the room temperature, and make up the volume of the remaining liquid to 50 c.c. by the addition of distilled water. Find the volume of soap solution necessary to produce a permanent lather by the method described above, and check the result obtained by similarly treating another sample. Should less soap solution be now required, part, at least, of the hardness is temporary, and the relative proportion of the hardness which is to be reckoned as of each kind may be roughly estimated from the readings obtained. Thus, suppose that 1 c.c. of solution was needed in the case of distilled water, and that the unboiled and boiled water required respectively 18 and 7 c.c. The total hardness will be represented, according to our standard, as $(18 - 1) = 17$. Of this $(7 - 1) = 6$ parts represent the permanent hardness, and hence the temporary hardness is $(17 - 6) = 11$.

To obtain strictly comparative results, more careful working than is outlined above is necessary, but the method employed is practically that described. The standard soap solution made use of in determinations of hardness is of such a strength that each c.c. used represents 1 mg. of dissolved calcium carbonate, and it is usual to express the results as degrees of hardness, one degree being equivalent to one part of calcium carbonate to 100,000 parts of water by weight. Thus, if the water examined is reported as possessing 15 degrees of hardness, 15 mg. of chalk, or its equivalent of other hardening salts, are presumed to be dissolved in 100,000 mg., or, what is practically the same, 100 c.c., of the water.

Examine the bottles in which the tests of the hardness of distilled and other water were made. In that containing the distilled water, the liquid will be found to be nearly clear, while the hard water bottle contains a very turbid liquid. The bluish white colour of the latter liquid is due to the presence of precipitated soap. Soap is a chemical compound, of which the chief constituent is—in the case of ordinary hard soaps—sodium stearate. The reaction between the soap and the calcium sulphate may be represented thus:

$$\left.\begin{array}{c}\text{Sodium stearate}\\+\\\text{calcium sulphate}\end{array}\right\} = \left\{\begin{array}{c}\text{sodium sulphate}\\+\\\text{calcium stearate.}\end{array}\right.$$

The precipitate consists of calcium stearate, which, being insoluble, is of no service for cleansing purposes. The sodium sulphate has no appreciable effect upon soap, and is not otherwise harmful when present in small quantities in washing water.

### *Exercise for Student.*

Write out the equations representing the reactions between soap and calcium bicarbonate, and bicarbonate and sulphate of magnesium.

61. In the experiment just described, the hard water, after enough soap solution has been added to produce a permanent lather, is said to be softened. The softening agent is soap, and if soap were cheap this method would be quite satisfactory for domestic

cleansing purposes. It has been shown, however, that one degree of hardness corresponds to about ten grains of soap rendered insoluble, and therefore useless, for each gallon of water used. Hence to soften 100 gallons of water of 20 degrees of hardness would involve the wastage of about 2 lb. 14 oz. of soap. In practice, therefore, large quantities of water are generally softened by the use of other agents. The one in most common domestic use is washing-soda, or sodium carbonate. This will remove both temporary and permanent hardness. The calcium or magnesium salts are in this case precipitated as carbonates, *e.g.*

$$\left.\begin{array}{r}\text{Calcium sulphate}\\ +\\ \text{sodium carbonate}\end{array}\right\} = \left\{\begin{array}{l}\text{sodium sulphate}\\ \quad\quad +\\ \text{calcium carbonate.}\end{array}\right.$$

Weight for weight, washing-soda possesses greater softening power than soap and, its cost being much less, its use is economical.

Experiment 45. Dissolve 3 g. of washing-soda in 100 c.c. of distilled water. Add 1 c.c. of this solution to 50 c.c. of ordinary tap-water. Similarly treat 50 c.c. of distilled water. Shake each mixture well and allow them to stand for a few minutes. Compare the clearness of the two liquids obtained. If the tap-water is hard, it will be distinctly more turbid than the distilled water.

To remove temporary hardness, a still cheaper and more efficient substance, lime, may be used. We have seen in Experiment 43 that the effect of adding lime-water to water containing bicarbonates in solution results in the formation of a precipitate of the carbonates. This reaction is applied in practice, in the Porter-Clark method of softening, by determining the amount of temporary hardness of the water, and then adding lime, mixed to a thin cream with water ("milk of lime") in approximately the calculated amount necessary for precipitation of the bicarbonates present. The water is allowed to remain in large settling tanks until the finely divided chalk has subsided, and is then run off for use.

Mere exposure to air in open vessels will slowly lessen the temporary hardness of water, owing to the gradual decomposition of the calcium bicarbonate and the escape of the resulting carbon dioxide. The action is extremely slow, however, and is of little service in practice.

To remove hardness of either kind entirely the water should be submitted to distillation. (See Part I, Chapter XVI.) This is the most expensive method, and is only made use of when the water contains other deleterious constituents which require removal.

62. Natural waters frequently contain finely divided matter in suspension. The removal of this may be effected by (*a*) allowing the water to remain undisturbed for a long period, when the floating material gradually subsides; (*b*) making use of a filtering medium, such as fine sand or porous earthenware; or (*c*) by a combination of both methods. The process of filtering is carried out on the large scale in the case of the water needed for the supply of large towns by letting it pass slowly through large filtering-beds, consisting of layers of gravel and sand of varying degrees of fineness, and then pumping it off to be supplied for household use. The process of filtration is also of assistance in removing the bacteria present in all waters. (See Chapter XII.)

For household purposes, the best filtering medium is provided by such a material as that used in the porous cylinders of the Berkefeld filter shown in Fig. 46. These are made from a special material with pores of suitable fineness, and when used with a water-supply of average pressure will supply about half-a-gallon of filtered water per minute. In the figure *S* represents the service pipe, *T* the tube from which the filtered water is delivered, and *U* a tap which may be used for flushing purposes. By loosening the flanged nuts shown at the top of the filter, the porous cylinder may be detached for sterilisation by heat. This is best effected by immersion for some minutes in boiling water, followed by thorough scrubbing. The film which forms on the outside of the cylinder and contains the bacteria removed from the water is thus

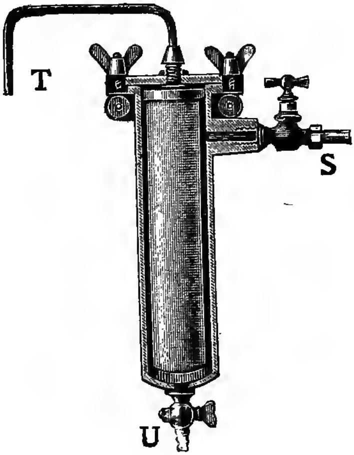

Fig. 46.

removed. Where water of doubtful character is passed through the filter, it should be sterilised weekly or, in the case of very bad water, every three or four days.

In the older forms of filter, porous porcelain or earthenware, sand, charcoal and other porous media were utilised. These materials were in general efficient as agents for the removal of suspended matter, but the comparatively large size of their pores rendered them almost useless for preventing the passage of bacteria. Unless very frequently cleansed, they merely became breeding-grounds for micro-organisms and hence their use increased instead of lessening any dangers arising from the use of the water passed through them.

The following experiment will give some idea of the power of charcoal as a filtering medium, although it is not certain that the action of this substance is entirely mechanical. It is thought that the peculiar power possessed by the charcoal of condensing gases within its pores may affect its action, since it is possible that oxygen or other gas thus condensed forms colourless compounds with the colouring matter in the liquids used.

EXPERIMENT 46. Powder some wood charcoal—preferably freshly prepared—in a mortar, and place it in a cone of filter paper supported by a glass funnel. Make a solution of litmus sufficiently strong to appear of a clear purplish-blue colour. Pour some of this solution through the prepared filter and compare the depth of colour of the filtrate with that of the original solution. It will be found to be of somewhat lighter hue. To increase the effect, heat some of the litmus solution till it is nearly boiling, and, while still hot, pour it through the filter. The colour may be entirely removed by a few repetitions of this process.

If animal charcoal—the charred residue derived from the destructive distillation of bones—be substituted for the wood charcoal, the result will be to hasten the decolorising action. That the loss of colour is due to the charcoal and not to the action of the filter paper may be readily demonstrated by attempting the experiment with filter paper alone as the filtering medium.

63. The examination of a sample of water for the presence of the other bodies mentioned as liable to be contained in it, is practically a matter of determining the suitability of the water for drinking. It is not feasible to carry out thoroughly such an examination without considerable analytical skill, but some preliminary evidence may be gathered by the performance of the various tests suggested below.

A potable water should be colourless, tasteless, and odourless.

Experiment 47. Fill a tall gas-jar with water. Stand it on a clean white tile, and examine the water by looking at it from above. It should be perfectly transparent, and the slightest yellowish tinge renders it suspect. To get rid of trouble due to crossing of lights, the tube should be placed facing a good light and the back of the tube may be covered, except for a small space near the bottom, by a sheet of white paper. A similar jar containing an equal quantity of distilled water may be placed side by side with the test jar for purposes of comparison.

Experiment 48. To determine whether the water is free from odour, half fill a small clean flask with it, cork the flask lightly with a clean cork, and warm it with its contents in a water-bath to about body temperature. Fix the cork in securely and shake well. Remove the stopper and smell the contents of the flask. Good water should possess no recognisable smell.

Tasting the water is a somewhat risky matter, if there be any grounds whatever for suspecting contamination. Freedom from colour, taste, and smell provides only negative evidence of the suitability of the water for drinking, since a sample may give no positive reaction when tested as above, and yet be most harmful as a beverage.

The proportion of solid matter in solution in a good water should not exceed about 35 grains per gallon or 50 mg. per 100 c.c. A rough estimate of the amount of dissolved solids in tap-water was described in Experiment 120, Part I. If a delicate balance be available, the experiment may be repeated, using in all 100 c.c. of the water to be tested. A higher result than that mentioned would cause the water to be looked upon with suspicion until further tests had shown that the high content of dissolved solids was capable of satisfactory explanation.

64. It is only possible to suggest qualitative tests for the other solid substances likely to be found. Of these, sodium chloride *per se* is harmless, but its presence in any quantity may show recent contamination with surface drainage water or with sewage effluent. It is usual to rely upon a test for chlorides to establish the possibility of its occurrence, since sodium is not easily tested for so as to obtain a conclusive result.

Experiment 49. Half fill a test-tube with the water. Add a few drops of silver nitrate solution. Should turbidity be produced after shaking, add a little weak nitric acid. A permanent turbidity, not cleared by the addition of the acid, is due to the precipitation of silver chloride, and indicates the presence of a chloride—probably sodium chloride. It will be found that all natural waters afford a certain degree of turbidity, but a little practice with different samples containing varying proportions of chloride will allow a rough deduction as regards the chloride being present in excess, or otherwise, to be made.

65. The nitrogen contained in all animal tissues produces during decay compounds of nitrogen of simpler composition than those found in the tissues themselves. The early stages of decomposition are marked by the formation of such ammonia, and this is slowly acted upon by oxygen under the usual conditions of decay, with the formation of compounds known as nitrites and nitrates. The nitrates are fully oxidised bodies, and are of themselves comparatively harmless, but water containing them in considerable amount labours under suspicion of contamination, and other noxious elements may be present in it which render it quite unwholesome.

Experiment 50. The presence of ammonia may be detected even when it occurs only in very small quantity by the use of Nessler's reagent. Partly fill each of two Nessler tubes—or other narrow jars made of clear glass—with 100 c.c. of the water to be tested. Add to one of the jars 5 c.c. of Nessler's reagent. Stir the reagent with the water by means of a clean glass rod.

Stand both jars upon a clean white tile, and examine the contents of each from above in a good light. A sample of water, free from all but the slightest trace of ammonia, should show only the faintest yellow tinge as compared with its untreated appearance. A distinct yellow or brown colour, or the production of turbidity, indicates water of doubtful quality.

EXPERIMENT 51. Nitrites may be indicated by placing 50 c.c. of water in a Nessler tube, adding one drop of strong hydrochloric acid, followed by a little solution of sulphanilic acid and an equal bulk of naphthylamine hydrochloride solution. The production of a reddish coloration within 20 minutes may be taken as evidence of the presence of nitrites.

EXPERIMENT 52. Boil about 100 c.c. of the water to dryness in a clean porcelain dish. Dissolve the residue by adding about 1 c.c. of strong nitric acid, and then add about 10 c.c. of a solution of ammonium molybdate. The production of a yellow colour or precipitate indicates the presence of phosphates, probably derived from contamination with animal matter.

The above tests, especially if repeated with samples of water to which *minute* quantities of the bodies to be tested for have been previously added, will serve to show the student the nature of the harmful impurities of organic origin that may be looked for, but the tests are only of value as indicating, should a positive result be obtained in any case, that the water is to be regarded with suspicion, and the services of a competent analyst should be engaged for the purpose of further and more exhaustive examination before using the water for drinking.

A simple test, upon the result of which too much reliance must not be placed, is the following, devised to indicate the existence of organic contamination by showing that the water contains dissolved matter ready to combine with oxygen, when the latter is presented to it in a suitable form.

EXPERIMENT 53. Pour into a tall glass jar about 200 c.c. of the water and into a similar jar the same quantity of fresh distilled water. Add to the contents of each vessel about 10 drops of strong sulphuric acid and just enough of a solution of potassium permanganate—Condy's fluid will do instead of this—to produce liquids of a similar faint pink tinge after thorough mixing. Cover each jar and allow to stand for a quarter of an hour. Should the liquid in the jar containing the sample of water undergoing the test have lost its colour entirely, or have paled to a much greater degree than the liquid in the other jar, organic matter of either vegetable or animal origin is probably present. The degree of wholesomeness of the water depends, of course, upon the depth of tint originally present and upon the extent to which this has faded.

66. Of the impurities likely to be introduced into water by its treatment before consumption, the one of chief importance is lead. This metal, in the presence of dissolved oxygen and carbon dioxide, is slowly attacked by water, and small quantities of it pass into solution. Since all lead salts are poisonous, and, moreover, their effect is cumulative, *i.e.* the effect of each successive dose imbibed is added to that of each of its predecessors, it is highly important that drinking water shall not contain even traces of this element.

Test the drinking water in your neighbourhood as follows:

Experiment 54. To a quantity of the water, contained in a tall glass vessel, standing upon a white surface, add a little hydrochloric acid and some solution of hydrogen sulphide or sulphuretted hydrogen. No coloration should be produced on stirring, and a yellow or brown colour or turbidity, caused by the precipitation of lead sulphide, is sufficient to render the water suspect.

As a check upon the result of the above test, boil down about 100 c.c. of the water to about one-tenth its bulk, and add to the remainder a little potassium chromate solution. A yellow precipitate of lead chromate—"chrome yellow"—shows that lead is present.

To show the delicacy of the above tests, add two drops of lead acetate solution to 500 c.c. of distilled water, and repeat the experiment.

It has been found that waters containing dissolved calcium sulphate or bicarbonate attack lead much less readily than water free from these bodies, but containing dissolved gases or acid bodies derived from peaty soils. The explanation suggested is that the lead reacts with the dissolved salts to form a sulphate or a basic carbonate of lead which is deposited upon the surface of the lead and protects it from further corrosion. The student should test this as directed in

Experiment 55. Boil some distilled water for 15 minutes, cool it in a closed vessel and pour it into a clean glass vessel so as to fill the vessel almost entirely. Into the water drop a piece of freshly scraped sheet lead.

Securely cover the mouth of the vessel, and allow it to stand for some weeks.

Place similar pieces of lead in other vessels filled with (*a*) unboiled distilled water which has been allowed to remain in contact with the air for some days; (*b*) a hard natural water, such as is frequently supplied for household use.

Compare the results of this treatment after some time, and try to draw inferences from the appearance of the various pieces of lead and from the appearance of the water, as to whether the lead has been attacked or otherwise in each case.

Water which has to be stored for any considerable period is best stored in tanks or cisterns made of other metals than lead, *e.g.* iron or zinc, and soft water should *never* be used for drinking after it has been allowed to remain in contact with lead. Some water supplies are artificially hardened by filtration through beds of chalk in order to minimise the risk of contamination with lead.

67. Mention has already been made of the presence of bacteria in natural waters and the breaking down of animal and vegetable substances is one of the results of their vital activities. In Chapter XII a further account of their nature will be found and methods for their destruction described. The removal of disease-producing bacteria from water used for drinking and cooking is a matter of great importance and may be effected by several methods. Prolonged boiling is the method most readily available in ordinary circumstances and water suspected of organic contamination should always be thus treated. Keeping the water at boiling-point for 20 minutes will kill most micro-

organisms, but a greater measure of safety may be attained by allowing the water to cool and repeating the boiling at the end of 24 hours. Further information on this matter will be found in Chapter XII.

## QUESTIONS

1. Mention the chief substances which may be found dissolved in a sample of spring water, and classify them according to their origin.

2. What tests would you apply to discover whether the water-supply of a farm was contaminated by sewage?

3. Explain clearly the formation of fur in a kettle. Of what substance does it chiefly consist and how may this substance be shown to be present?

4. Give clear directions for determining whether a given sample of water is hard or soft, and also how to distinguish between temporary and permanent hardness.

5. Why is lead an unsuitable material for the construction of household utensils required for cooking?

6. Certain gases may be found in solution in all natural waters. Mention the most important of these, and briefly indicate how the sanitary character of the water may be affected by their presence.

7. A given water-supply is found to effervesce when the water is freshly drawn. To what do you ascribe this phenomenon? Would you consider such water fit for drinking? If not, give reasons for your opinion.

8. Suggest a method of showing the delicacy of the test for ammonia described in the text.

9. What means would you adopt, pending the report of an analyst, to prevent serious effects resulting from the use of a drinking water, which you suspect, as a result of your own examination, to be contaminated with matter of organic origin? No other supply is supposed to be available.

# CHAPTER VI

## SALT AND ITS DERIVATIVES

68. Common salt is the parent substance whence many other useful substances are obtained, and it will be of interest to follow out the stages whereby the latter are produced from salt by suitable chemical reactions.

Two sources of supply are known in Nature, and from each large quantities of salt are obtained yearly. Sea-water is a solution of several mineral substances, of which salt, or sodium chloride, as it is termed by the chemist, is the most important. About three per cent of sea-water by weight consists of salt in solution. Salt is also found in considerable quantity as a mineral deposit in the form of large crystals, usually of a brownish tinge through small amounts of iron chloride being present, and in this form is known as rock salt. The rock salt beds probably represent the residue left after the evaporation of the water of ancient seas. At Wielicza, in Galicia, there is an enormous bed, said to be 500 miles long, 30 miles broad, and 1200 feet thick. Salt has been removed from this deposit continuously for some 600 years.

Salt is obtained from sea-water by evaporation of the latter in warm countries, using the sun's heat, large surfaces of water being exposed in shallow pits near the shore so that the winds may assist in removing the vapour. In cold regions the water is frozen, pure ice separating out first, and the stronger solution of salt resulting being further concentrated over fires. The former method is in use on the shores of the

Mediterranean, while an example of the latter is afforded by the practice of the dwellers on the shores of the White Sea.

Rock salt is frequently dug out, or mined, like other minerals, as is the case in the Galician salt-mines. At the Cheshire beds, another device is generally used for obtaining the salt from the deposits. Water is forced into the bed by means of a bore-hole, or well, constructed for the purpose. After it has been left in contact with the salt for a sufficient length of time, the brine is pumped to the surface by powerful pumps, and is concentrated by evaporation.

POTASSIUM CHLORIDE.

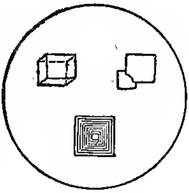

Fig. 47.

Crystals of salt are of a dazzling white colour and cubic in shape, resembling those of potassium chloride shown in Fig. 47. They do not contain "water of crystallisation" and, when heated, do not melt below a red heat.

Experiment 56. Place a little salt in a hard glass tube, closed at one end. Heat the salt with a strong Bunsen flame. A crackling noise is frequently to be heard at an early stage of the heating. This is due to breaking up of the crystals by the escape of a little water, which is commonly found within the crystals, not combined, but simply mechanically mixed with the salt. The crackling is termed "decrepitation". At a later stage the salt melts, forming a clear liquid, which again forms a crystalline mass on cooling. The temperature of fusion is about 800° C.

It may be that a deposit, consisting of small drops of water, will form upon the cooler part of the tube during this experiment. This must not be considered as evidence that water forms an essential constituent of salt. In the crude state salt is generally contaminated with small quantities of the chloride of magnesium. This substance readily absorbs moisture, and, unless the salt is purified, will cause it to become damp in moist weather. Salt itself does not deliquesce, *i.e.* tend to become liquid, when exposed to a moist atmosphere.

Salt is fairly soluble in water at ordinary temperatures, 100 parts by weight of water dissolving about 36 parts of salt. It exhibits a peculiarity in its behaviour in that it is almost as soluble in cold water as in hot, 100 parts of water at its boiling-point only dissolving some 39 parts of salt.

EXPERIMENT 57. Weigh out roughly 50 g. of finely powdered salt, and transfer it to a beaker containing 100 c.c. of distilled water. Make a saturated solution of salt at the temperature of the water by stirring the salt with the water for about 20 minutes. Pour off the liquid from the undissolved residue through a filter. Add 5 g. of salt to the filtrate and bring the liquid to the boiling-point. If the original solution was really saturated, it will be found that the salt added will not entirely dissolve even in boiling water.

EXPERIMENT 58. Mount a piece of platinum wire about 2 inches long in a glass holder by drawing out a small piece of glass tubing to form a jet, inserting the end of the wire into the open end of the jet, and fusing the wire and glass together in a Bunsen flame. Heat the end of the wire in the flame and, while still hot, touch some salt with the tip. Replace the tip of the wire in the outer mantle of the flame near the bottom. A vivid yellow coloration will be given to the flame by the burning of a little of the sodium vapour volatilised by the heat.

The production of this yellow colour is the most characteristic test for the presence of sodium in a substance. It may readily be shown that this element is present—in small proportions—in the air and in almost all other bodies.

Experiment 59. Watch the outer mantle of a Bunsen flame. Small yellow flashes betoken the passage of particles of dust through the flame, each particle bearing its minute load of sodium chloride. Place a duster or other piece of cloth on the bench near the flame. Strike the duster sharply with the open hand. A shower of small dust particles will be produced, and the flame will immediately show their presence.

The sodium is usually present in the form of sodium chloride, and it is supposed that this substance is derived from the evaporation of spray blown from the surface of the sea by the wind, and then carried by the wind into districts remote from the sea.

69. We will next trace the progress of each of the elements sodium and chlorine contained in salt through a series of chemical changes, in each of which a substance of great value commercially is obtained.

Experiment 60. Fit up the apparatus shown in the figure on p. 132. The flask contains sufficient rock salt —or lumps of fused salt—to cover the bottom with a single layer. Sulphuric acid is poured down the thistle funnel until the salt is just covered. The acid should be first diluted somewhat. This may best be done by slowly pouring some of the commercial acid into one-half its bulk of water contained in a beaker or other thin-walled glass vessel.

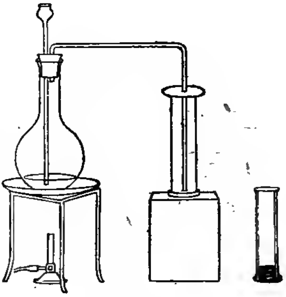

Fig. 48.

Gently heat the contents of the flask, and collect the gas evolved by the method of upward displacement of air. Dry jars should be used. The gas is colourless, but produces greyish fumes when in contact with air. Hence it is easy to discover when a jar is full by watching the opening in the cardboard cover placed upon the mouth. Collect four jars for use in the succeeding experiments.

The reaction which occurs in the above experiment is represented by the following equation:

$$\left.\begin{array}{c}\text{Hydrogen sulphate}\\ + \\ \text{sodium chloride}\end{array}\right\} = \left\{\begin{array}{c}\text{sodium hydrogen sulphate}\\ + \\ \text{hydrogen chloride.}\end{array}\right.$$

The sodium hydrogen sulphate remains in solution in the hot liquid in the flask, and may be obtained in a crystalline form by cooling. The hydrogen chloride is the gas collected, and contains the chlorine from the salt used.

EXPERIMENT 61. Plunge a lighted taper into one of the jars of gas. The taper is extinguished and the gas does not ignite. That is to say, the elements carbon and hydrogen present in the taper have no tendency to unite with hydrogen chloride, and the latter has no tendency to combine with the oxygen of the air.

Experiment 62. Invert another jar in a trough partly filled with water and withdraw the glass plate while the mouth of the jar is under water. The rapid rise of the liquid in the jar shows that hydrogen chloride is very soluble in water. Replace the glass plate when no further rise in the level of the water can be noted, and remove the jar from the trough. Drop red and blue litmus papers into the water in the jar. The change in the colour of the latter shows that hydrogen chloride forms an acid when dissolved in water.

Experiment 63. Cautiously smell the contents of the third jar. The smell of the gas is extremely pungent, *i.e.* it irritates the nose and tends to produce coughing or sneezing. (The student should note that a "pungent" smell is not necessarily either powerful or particularly unpleasant, but is one which irritates the nose by producing a pricking or tickling sensation.) After smelling the gas, turn the jar upside down, remove the plate, and after half a minute insert a lighted taper. The continued burning of the taper indicates that the gas has escaped from the jar, being considerably denser than air.

Experiment 64. Dip a glass rod into a little strong solution of ammonia and plunge the wetted rod into the fourth jar. Dense whitish fumes will be formed around the rod. These are fumes of ammonium chloride, produced by the direct combination of the ammonia with the hydrogen chloride.

Experiment 65. To obtain some solution of the gas for testing purposes, remove the delivery tube of the apparatus in which the gas was prepared, and substitute the arrangement shown in Fig. 49. Place the rim of the funnel in contact with the surface of some distilled water in a large beaker. Heat the flask containing the sulphuric acid and salt, and allow the gas to pass into the water for some minutes. Note that very few bubbles of gas escape from the end of the funnel, and that the solution of the gas formed near the surface of the liquid is denser than water, as shown by the streams of solution which may be seen descending from the mouth of the funnel.

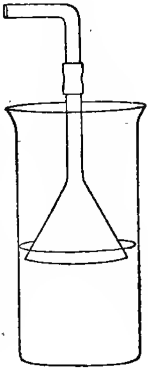

Fig. 49.

Experiment 66. To separate portions of the solution obtained, add the following:

(*a*) a little blue litmus solution;
(*b*) a small piece of zinc;
(*c*) a crystal of washing-soda;
(*d*) a small lump of marble;
(*e*) a few drops of litmus solution and then, little by little, just enough solution of caustic soda to turn the colour of the liquid to a purple tint.

Evaporate the solutions obtained in (*c*) and (*e*) to dryness, and taste the residue.

The results obtained by performing the above tests show that the liquid answers to the description of an acid given in Part I, Chapter XVIII. It is known as hydrochloric acid, its earlier names being spirit of salt or muriatic acid. (Lat. *muria*, brine.) The reasons for giving it these latter titles are evident from consideration of the method by which it was obtained.

Large quantities of hydrochloric acid are manufactured by making use of the reaction between strong sulphuric acid and salt. The reaction is usually carried a step further than was done in the above laboratory preparation. At a red heat the whole of the hydrogen in the sulphuric acid is displaced in combination with chlorine, the following equation being realised:

$$\left.\begin{array}{c}\text{Sodium chloride}\\+\\\text{hydrogen sulphate}\end{array}\right\}=\left\{\begin{array}{c}\text{sodium sulphate}\\+\\\text{hydrogen chloride.}\end{array}\right.$$

70. From the solution of hydrogen chloride, the element chlorine may be separated as follows:

EXPERIMENT 67. Fit up the apparatus employed in the preparation of hydrogen chloride. Cover the bottom of the flask with small lumps of manganese dioxide. Pour down the thistle funnel enough strong hydrochloric acid (the solution obtained by causing as much hydrogen chloride as possible to be dissolved in water) to cover the manganese dioxide. Place the apparatus in a fume-chamber. Gently heat the contents of the flask, and note the evolution of a yellow gas. This gas may be collected by upward displacement of air. Collect five jars.

The yellow gas is chlorine, a gaseous element.

Equation:

$$\left.\begin{array}{c}\text{Manganese dioxide}\\+\\\text{hydrogen chloride}\end{array}\right\}=\left\{\begin{array}{c}\text{manganese chloride}\\+\\\text{hydrogen oxide}\\+\\\text{chlorine.}\end{array}\right.$$

Caution. Avoid smelling the gas directly. An idea of its powerful suffocating smell will be acquired during the performance of this and other experiments with it, and it should be noted that an incautious breathing of the undiluted gas may be attended with fatal results. The gas attacks the mucous membranes of the nose, throat and lungs, destroying them, and thus causing suffocation.

Experiment 68. Plunge a lighted taper into a jar of chlorine. It will be found that the gas is non-inflammable, while the taper continues to burn with an extremely smoky reddish flame. The hydrogen of the taper combines with the chlorine to form hydrogen chloride, while the carbon, which is unable to combine directly with that gas, is set free in the form of soot.

Experiment 69. Warm a little turpentine (a compound of carbon and hydrogen) in a porcelain dish in the fume cupboard. Dip some cotton-wool into the warm liquid. Drop the wool into another jar of chlorine. The vigorous nature of the combination of hydrogen with chlorine will be shown by the rapid combustion of the turpentine, attended by the formation of dense clouds of soot.

Experiment 70. Hold a bunch of flowers in a jar of the gas. The colour will be discharged and the petals will become white. This action is known as bleaching. Chlorine will bleach vegetable colours rapidly.

Experiment 71. Into another jar of chlorine drop a small piece of cloth, dyed with Turkey red or with indigo, and moistened with water. The colour will soon be destroyed, and a white or faintly yellowish rag will remain.

Repeat the test with a similar piece of cloth which has been thoroughly dried and with a jar of chlorine which has also been dried by pouring in a little strong sulphuric acid and allowing it to remain in contact with the gas for 20 minutes. It will be found that bleaching does not occur, or, if it does, it is very slow and indicates that the drying was incomplete. Moisture must evidently be present in order that the bleaching properties of chlorine may be rendered manifest.

The chlorine reacts with water in such a way that the oxygen of the latter is displaced and hydrogen chloride is formed:

Chlorine + hydrogen oxide = hydrogen chloride + oxygen.

The bleaching is attributed to the action of the oxygen upon the colouring matter, and the fact that ordinary oxygen is unable to effect this change is sometimes explained by assuming that the newly formed oxygen is more energetic than it becomes after it has existed in the free state for a short time. It is supposed that the oxygen at the moment of liberation is in the form of atoms, while, if left to itself, these atoms form groups of two, termed molecules (see Part. I, par. 180). The extra energy of the atoms is ascribed to their not having lost part of their energy by thus forming molecules, the constituent atoms of which expend a certain amount of energy in uniting.

*Note.* An alternative explanation of the bleaching is that the action of cold water upon chlorine is not of the simple character stated above. The following equation represents this:

$$\left.\begin{array}{c}\text{Hydrogen oxide}\\+\\\text{chlorine}\end{array}\right\}=\left\{\begin{array}{l}\text{hydrogen chloride}\\\quad\quad\quad+\\\text{hydrogen hypochlorite}\\\quad\text{(hypochlorous acid).}\end{array}\right.$$

Hypochlorous acid is an unstable compound, and is readily decomposed with the evolution of considerable energy, which is usually rendered sensible in the form of heat. Its decomposition is shown as follows:

Hydrogen hypochlorite = hydrogen chloride + oxygen.

The bleaching action is considered to be due to this decomposition being effected in contact with the colouring matter, and the extra energy required by the oxygen to effect the bleaching is supplied by the energy set free during the splitting up of the hypochlorous acid, some of which takes the form of chemical energy instead of heat.

EXPERIMENT 72. Into another jar of chlorine drop a sheet of Dutch metal—a form of brass, sold in thin sheets, resembling gold leaf. The metal combines with the chlorine with such avidity that it becomes red-hot. The yellowish-green fumes produced are those of small particles of copper chloride, copper being the chief constituent of the Dutch metal.

Other metals are similarly attacked by chlorine, especially when finely divided or in the form of thin sheets. Bulky masses of metal are first attacked on the outside, and prolonged action results in the corrosion becoming considerable.

71. Chlorine is manufactured on the large scale for use in making bleaching powder. This is obtained by allowing chlorine to act upon slaked lime in the form of fine powder. The product is a creamy white powder with a slight odour of the gas. It is of great value as a bleaching agent. Acids, even so weak an acid as carbonic acid, liberate chlorine from it readily.

Experiment 73. Cover the bottom of a gas-jar with a thin layer of bleaching powder. Pour into the jar enough hydrochloric acid to cover the powder. Chlorine is evolved at once, and the jar may be readily filled by this means.

Repeat the above operation, using in turn sulphuric, nitric, and acetic acids.

Experiment 74. Dissolve about 5 g. of tartaric or phosphoric acid in 100 c.c. of water. To the solution add enough gum dextrin to make it sticky. With the liquid thus obtained draw or stencil a design on a piece of cloth dyed with a vegetable dye. Dry the wetted parts of the cloth. Prepare two vessels containing some bleaching powder stirred up with water, and plain water respectively. Dip the cloth in the former and allow it to remain for about a minute. Remove it and plunge it into the water in the other vessel. Squeeze it well between the fingers to remove as much as possible of the bleaching solution. Examine it after this treatment. It will be found that the part of the cloth upon which the design was drawn is now white. Should it not be so, a repetition of the treatment will usually be sufficient to effect complete bleaching.

Coloured cloth is frequently dealt with in similar fashion to the above, when a white pattern is required to appear upon a coloured ground. Very careful washing is needed after the bleaching in order to remove the last traces of the hydrochloric acid produced by the decomposition of the hypochlorous acid first formed.

The production of bleaching powder does not lend itself readily to demonstration in the laboratory, but a valuable bleaching agent may be prepared by a somewhat similar reaction.

Experiment 75. Dissolve about 10 g. of potassium hydroxide (caustic potash) in 100 c.c. of water. Place the vessel containing the solution in a trough of cold water in a fume-chamber. Pass a steady stream of chlorine through the alkaline liquid for several minutes. This may be done by fitting up the apparatus shown in Fig. 50.

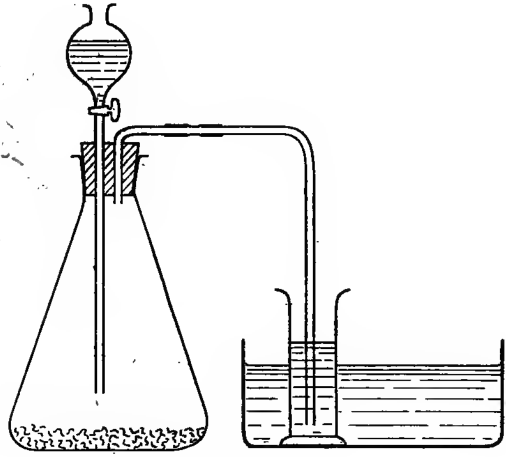

Fig. 50.

The flask contains bleaching powder, and strong hydrochloric acid is allowed to drip slowly on the powder from the tap-funnel. Or a Kipp's apparatus may be used, in which the middle bulb is partly filled with small cubes of bleaching powder mixed with a little plaster of Paris, and with an acid, such as hydrochloric, in the lowest chamber and reservoir.

A solution of potassium hypochlorite containing some potassium chloride is thus obtained:

$$\left.\begin{array}{l}\text{Chlorine}\\ \qquad + \\ \text{potassium hydroxide}\end{array}\right\} = \left\{\begin{array}{l}\text{potassium hypochlorite}\\ \qquad\qquad + \\ \text{potassium chloride} + \text{hydrogen oxide.}\end{array}\right.$$

This liquid is known as "Eau de Javelle" and may be used for simple bleaching operations where vegetable colours are concerned.

Experiment 76. Make a blot, or write, with ordinary writing ink upon a sheet of printed matter. Carefully paint the blot or writing, when dry, with a little of the solution just prepared. Allow the liquid to remain in contact with the paper for a short time and then remove as much as possible with absorbent paper. Wash the part treated by painting it two or three times with clean water, absorbing the water each time with blotting-paper. It will be found that the writing ink may be removed with more or less success without damage to the printed matter. Printer's ink owes its colour to finely divided carbon—lampblack—and this material, as we have already observed in Experiments 68 and 69, is not attacked by chlorine.

72. In the substances produced from common salt with which we have been concerned up to this point, the element chlorine from the salt has been contained. We will next trace its fellow, sodium, through a series of changes in which other useful substances are formed.

When dealing with the manufacture of hydrochloric acid from salt, it was stated that the action of sulphuric acid upon salt resulted in the production of sodium sulphate. This substance is of considerable value to the glassmaker and dyer, while a certain amount finds a somewhat questionable use as a "filling" for cold water soaps, and the purified substance is used in medicine under the title of "Glauber's salt". When obtained, together with other bodies, in the above manufacture, it is termed salt-cake. It is mixed with the proper quantities of chalk and coke or small coal, and is then heated strongly in special furnaces. As the result of several reactions, the greater part of the sodium appears in the product as sodium carbonate. The product—"black ash"—is treated in a series of large tanks with several successive quantities of water to dissolve the sodium carbonate. The solution is evaporated down and allowed to cool. Clear glass-like crystals of sodium carbonate—washing-soda—separate out. These contain a very large proportion of water—or rather, hydrogen and oxygen in the same proportion by weight as in water—and, in order to obtain sodium carbonate itself, this "water of crystallisation", as it is termed, may be driven off by heat.

EXPERIMENT 77. Place a few grams of washing-soda crystals in a small porcelain dish. Heat the dish and its contents over a small Bunsen flame. Watch the behaviour of the soda, and, when no further action occurs, examine the product. This is "anhydrous" sodium carbonate, *i.e.* sodium carbonate deprived of the elements of water.

$$\text{Sodium carbonate (hydrated)} = \left\{\begin{array}{l}\text{sodium carbonate (anhydrous)} \\ \qquad\qquad\qquad + \\ \text{hydrogen oxide.}\end{array}\right.$$

Sodium carbonate crystals lose some of their water of crystallisation when exposed to the air, even without the application of heat.

EXPERIMENT 78. Weigh out about 10 g. of clear small crystals of washing-soda into a weighed porcelain dish. Allow the dish and its contents to stand in a dry place free from dust for several days. Examine the contents of the dish daily, and also note any change in weight. It will be found that the crystals slowly become covered with a white powder, and that the weight decreases steadily.

Substances which behave similarly to washing-soda in giving up water of crystallisation on exposure are said to "effloresce", and the phenomenon is known as "efflorescence". This may be considered as the reverse of deliquescence (see earlier part of this chapter.)

The method of making sodium carbonate from sodium chloride outlined above is due to Leblanc. His process was first worked on the large scale in France at the time of the Revolution. The import of soda had ceased as the result of the action of Napoleon in closing French ports to English and American ships. Until 1793 the chief source of the carbonate had been the ashes produced by the burning of seaweed. Napoleon offered a prize of 100,000 francs for a commercial method of obtaining it from common salt, this prize being awarded to Leblanc.

The Leblanc process is still worked, but not primarily as a means of procuring sodium carbonate. The other substances, such as hydrochloric acid, formerly wasted, have become of great commercial importance, and the method is now used largely for the preparation of such "by-products".

The chief rival of the Leblanc process is the "ammonia-soda" process of Solvay. In this, carbon dioxide and ammonia are passed through sodium chloride solution in towers of special construction. The reaction which takes place involves the production of sodium bicarbonate and ammonium chloride. Both these salts are soluble in water, but the bicarbonate much less so than the chloride. The crystals which separate out first from a concentrated solution of these bodies consist of practically pure sodium bicarbonate. To transform the bicarbonate into the carbonate, it is heated.

Experiment 79. Place about 2 g. of bicarbonate of soda in a test-tube and heat, with the tube in a horizontal position, in a Bunsen flame. Steam will be produced and some of this will condense as small drops of water on the interior of the tube. Hold another test-tube containing a little lime-water with its mouth just below that of the other tube. After a few seconds, shake the tube and lime-water. The production of considerable turbidity will show that carbon dioxide is also given off when the bicarbonate is heated.

$$\text{Sodium hydrogen carbonate} = \begin{cases} \text{sodium carbonate} \\ \quad + \\ \text{hydrogen oxide} \\ \quad + \\ \text{carbon dioxide.} \end{cases}$$

The normal carbonate may be transformed into the bicarbonate in the following manner.

Experiment 80. Dissolve about 1 g. of washing-soda in water. Test the reaction of the solution toward litmus paper. It will be found to turn red litmus paper blue. Sodium carbonate is therefore a salt with an alkaline reaction. (See Part I, Chapter xviii.) Pass carbon dioxide through the solution for several minutes and again test the reaction of the liquid. It will probably be still alkaline. Continue passing the gas, testing the reaction of the liquid at intervals.

A stage will at length be reached when the reaction is practically neutral, or at most very faintly alkaline. The liquid is now a solution of sodium hydrogen carbonate, produced according to the equation:

$$\left.\begin{array}{c}\text{Sodium carbonate}\\+\\\text{carbon dioxide}\\+\\\text{hydrogen oxide}\end{array}\right\} = \text{sodium hydrogen carbonate.}$$

The bicarbonate cannot be obtained in solid form by evaporation of the solution, since it is decomposed by heat.

*Exercise for Student.*

What other bicarbonates behave similarly to sodium bicarbonate with reference to their behaviour when heated?

73. Sodium carbonate was known in early days as a "mild" alkali, in contradistinction to the "caustic" alkali, sodium hydroxide, or hydrate, as it is less correctly called. The carbonate may be transformed into the hydroxide by the action of slaked lime.

EXPERIMENT 81. Make a solution of washing-soda by dissolving 20 g. in 200 c.c. of water. To this add about 20 g. of slaked lime. Boil the mixture for some time in a beaker with a clock-glass or porcelain dish upon its mouth to prevent too much liquid being lost by evaporation. From time to time filter a few drops of the mixture, and add a little hydrochloric acid to the filtrate. When effervescence ceases to be produced on heating the filtrate in this manner, stop the heating, and filter the whole of the liquid. Boil down the filtrate to dryness in a porcelain dish. The resulting solid is a sample of the caustic alkali, sodium hydroxide.

### *Exercise for Student.*

Verify the statement that the residue just obtained is an alkali by performing the tests suggested in Part I, Chapter XVIII.

Caustic soda is made on the large scale by a suitable modification of the above process, but in the ready production of the hydroxide by modern electrolytic processes, the older process has a formidable rival.

74. Most of the substances which we have shown may be produced from the parent substance, common salt, are of very considerable use in household matters, as well as in the arts and manufactures.

Salt itself is used as a condiment and preservative, and also in the manufacture of soap and as a glaze for some kinds of earthenware.

Sodium sulphate, when mixed with half its weight of strong hydrochloric acid, forms an excellent freezing mixture.

Sodium carbonate, in the familiar form of washing-soda, is of great value as a water-softener and soap-saver in the laundry.

Baking-soda, or bicarbonate of soda, finds application as a raising agent in cookery.

Caustic soda is the alkali of most general service in the arts and manufactures. It is used in large quantities for soapmaking, papermaking, bleaching and dyeing.

Hydrochloric acid is sometimes used as a disinfectant and is sold under the name of "spirit of salt" for the tinman's use. It also finds very considerable application in calico printing and dyeing and is one of the most valuable laboratory reagents.

Chlorine is also a most powerful disinfectant. Its value as a bleaching agent has been already referred to, and it is made on the large scale for use in the manufacture of bleaching powder.

The contents of the foregoing chapter will serve to give the student an idea of the services rendered to household affairs and to the various arts by chemical research, and will emphasise the importance of the close inter-relation of the work of the laboratory scientist with that of the worker in the domain of the arts and manufactures.

## QUESTIONS

1. Washing-soda and spirit of salt may both be obtained from salt by suitable chemical interactions. Describe a method of reproducing a sample of salt from these materials.

2. Suggest a method of removing an ink-stain from a white cotton dress.

3. Starting with baking-soda, how may some caustic soda be prepared?

4. By what tests would you distinguish a sample of salt from one of baking-soda?

5. Give an account of some experiments which show the very energetic character of the combination of hydrogen with chlorine.

6. What would you do in order to find out whether a sample of washing-soda was contaminated with bicarbonate of soda?

7. In what way is the bleaching effect of chlorine explained? Why does oxygen in the free state possess less bleaching power than when evolved in contact with the material to be bleached?

8. State some reasons, based upon your practical work with chlorine, why chlorine is not used more generally as a disinfectant.

9. Give in outline a description of the Leblanc process for the manufacture of sodium carbonate.

10. If you were supplied with some common salt, sulphuric acid, manganese dioxide, and quicklime, what substances could you prepare? Describe briefly the method you would adopt to obtain a sample of each of the substances you mention.

# CHAPTER VII

## CLEANSING AND BLEACHING

75. The method adopted to remove dirt depends upon the nature of the latter and upon the closeness of its association with the material to be cleaned. Dirt which is merely present on the surface of an article may usually be got rid of by the act of rubbing. Thus dust and mud are brushed from clothing without the assistance of a special substance capable of attacking the dirt in any way. On the other hand, grease stains or paint marks cannot be removed by brushing or rubbing, but require the action of some substance which will absorb or dissolve the grease or paint. Both methods of removal of dirt are frequently taken advantage of in combination, *e.g.* in the act of washing one's hands, they are rubbed together and soap is also made use of to help in the cleansing. The operations involved in cleansing will be considered in greater detail in the succeeding paragraphs.

76. The mechanical removal of dirt may be effected by the use of special appliances, such as brushes or "vacuum" cleaners, or by rubbing with powdered substances, such as emery or whiting, the cleansing agent being either used dry or with the addition of water.

When brushes are used without other material, the effect of the brushing frequently amounts to the removal of the dirt into the air, followed by its subsequent settlement elsewhere. To obviate this, it is a common practice to use damp tea-leaves or sawdust when brushing floors, in order that the damp particles may act as nuclei for the attachment of the dust. Special preparations are also sold for the purpose, for some of which it is claimed that they also act as disinfectants. Another good method of preventing the "raising of the dust" is to sprinkle the floor with a weak solution of a disinfectant before sweeping. A modern device which has attained some popularity is the so-called "vacuum" cleaner. In this appliance, the dust is caused to pass through an opening, which is brought into contact with the article to be cleaned, into a receptacle attached to the machine, by the action of a suction pump worked by the muscles of the sweeper or, in the more expensive varieties, by a small electric motor which may be attached to the lighting supply. The efficiency of these cleaners appears to depend somewhat upon the exercise of due care and perseverance by the operator.

The value of the various powders depends upon their power as "abrasives", *i.e.* upon the scratching away of the particles of dirt by the rubbing against them of the particles of powder. Some substances in common use for this purpose are sand (silicon dioxide), emery (aluminium oxide), rouge (iron oxide), putty powder (tin dioxide), and whiting (calcium carbonate). In many cases the powders are composed of materials which are harder than the surfaces of the substances to be cleansed, and this results in a portion of the surface of the material being removed during the cleaning process, causing the powder to have a polishing effect. The best results are obtained when the particles of powder are very fine, the amount of surface removed being then least. Large particles leave scratches on the surface visible to the naked eye. The scratches made by very fine particles blend together to produce a glossy surface.

Water is commonly used as a medium for preventing the production of dust when using powders as cleansers, and also as a lubricant, assisting in the latter case to prevent scratching. It is often used alone for cleaning purposes and dirt which is only loosely held in contact with the material to be cleaned can often be readily removed by rubbing in the presence of water. The motion of the water floats away the particles of dirt and its action in this respect is entirely mechanical.

There is, however, another side to the action of water as a cleansing agent. It is the solvent of most universal application, and a great part of its cleansing power may be attributed to this property. Many stains on cloth, such as those of tea or fruit, may be removed if *immediately* treated with plenty of water. Should the stain be allowed to remain for a comparatively long time, however, and to become dry, the staining substance may react with the stained material, and in this case resort must be had to special methods of removal.

Other solvents of value for special purposes are methylated spirit (ethyl or ordinary alcohol to which about 10 per cent of methyl alcohol—wood-spirit—has been added, together with just enough paraffin to render it slightly turbid on the addition of water), turpentine, ammonia solution, carbon disulphide, ether, and benzene. Stains produced by fatty matter are not dissolved by water and the use of a solvent for the grease, such as petrol or benzene, is necessary, if preliminary treatment with a warm iron placed over clean blotting-paper or fuller's earth has been ineffective.

These solvents are volatile liquids and their vapours form explosive mixtures with air. Hence great care must be exercised in their use and they must on no account be used in the neighbourhood of a naked flame. To obtain the best results, the solvent should not be placed directly upon the grease-spot, as this usually brings about the spreading of a solution of grease in the solvent around the original stain, the mark left after the evaporation of the solvent being larger than that originally present. The solvent should be poured in a circle around the spot and worked towards it with a clean soft rag. The dissolved grease then collects at the centre and may be removed, together with excess of solvent, by absorbent paper.

77. The action of water is greatly assisted by the addition of certain other materials, paramount among these being soap. The nature and cleansing action of soap deserve somewhat fuller treatment than can be spared for most of the remaining substances of value as cleansers.

Soap is a salt, or more commonly, a mixture of salts. The acid (or acids) concerned in the composition of soap belongs to the same group as acetic acid—the acid of vinegar—or to other closely allied groups. The chief acids are stearic, palmitic, and oleic. Their main point of difference from acetic acid is that their molecules contain much larger numbers of atoms of carbon and hydrogen. Thus the formula of acetic acid is $C_2H_4O_2$, while that of stearic acid is $C_{18}H_{36}O_2$. We have learnt in Part I, Chapter XVIII, that the neutralisation of acids by alkalis produces salts. When stearic acid is neutralised with caustic soda, the salt formed is a soap. The latter substance is not, however, commonly made by causing an alkali to react with one of the "fatty" acids, as they are called. Advantage is taken of the power possessed by the strong alkalis of removing weaker bases from combination with acids, the metal of the strong alkali combining with the acid residue to form a new salt. The common fats and oils are salts of the fatty acids with a weak base, glyceryl, which exists in combination with the radical hydroxyl as glycerine or glycerol.

*Note.* A "radical" is a group of elements which behaves in many ways as if it were a single element. Thus the group hydroxyl, consisting of one atom of hydrogen and one atom of oxygen, is the radical common to all the bases and may be transferred from one to another by suitable reactions without separation of the hydrogen and oxygen.

Prolonged action of a caustic alkali upon a fat results in the glyceryl being removed in combination with the hydroxyl of the alkali as glycerine, and the formation of a soap in which the metal contained in the alkali is combined with the radical of the fatty acid.

EXPERIMENT 82. Mutton tallow chiefly consists of glyceryl stearate. Weigh out roughly 50 g. of good mutton tallow and place it in a large porcelain dish or small iron saucepan. Add about 60 c.c. of water. Make a solution of caustic soda by dissolving 15 g. in 120 c.c. of water, and add about half this solution to the contents of the dish. Heat the dish and its contents till the liquid boils. Continue the heating for about an hour, adding small quantities of water from time to time to replace that lost during boiling. Next add the remainder of the alkaline solution and again boil for another hour. Add water as before to compensate for that which boils away, gradually lessening the replacement, so that, at the end of the operation, the volume of the contents of the dish has diminished by about one-third. Throw in about 25 g. of common salt, boil for five minutes, and allow to cool. The soap will rise to the top of the cold liquid, while the salt, glycerine and unused caustic soda will be contained in the watery liquid beneath. Remove the layer of soap by skimming as completely as possible and purify it by dissolving in 100 c.c. of hot water, boiling for ten minutes, and salting out once more. The soap may be dried, after removal from the dish, by squeezing between layers of absorbent paper, followed by exposure to the air in a warm place.

The reaction occurring in this experiment may be represented thus:

$$\left.\begin{array}{c}\text{Glyceryl stearate}\\ \text{(mutton fat)}\\ +\\ \text{sodium hydroxide}\\ \text{(caustic soda)}\end{array}\right\} = \left\{\begin{array}{c}\text{glyceryl hydroxide}\\ \text{(glycerine)}\\ +\\ \text{sodium stearate}\\ \text{(hard soap).}\end{array}\right.$$

Soap is soluble in water but is insoluble in fairly strong brine. Hence the use of salt to cause the separation of the soap.

EXPERIMENT 83. Dissolve about 3 g. of salt in 100 c.c. of distilled water. This solution roughly represents sea-water. Try to wash the hands, using ordinary soap and the salt solution just made.

### *Exercise for Student.*

Explain why it is difficult to cleanse the hands in this experiment.

If caustic potash be substituted for caustic soda in Experiment 82, the soap produced will be different in character and is a sample of the variety known as soft soap. Salting out is usually omitted in the manufacture of soft soaps, the liquor being concentrated by boiling until of the proper consistency and the glycerine and a small excess of alkali being left in the finished product.

The question of the reaction which occurs when soap is added to hard water is dealt with in Chapter v. The turbidity or scum produced during such action is caused by the formation of soaps containing calcium or magnesium in place of sodium or potassium. Such soaps are insoluble in water and are useless as cleansing agents.

78. In making soap the weak base glycerol is replaced by the more powerful base caustic soda. In similar fashion, the weak acids contained in soap may be replaced by stronger acids, such as hydrochloric and sulphuric. The fatty acids, being themselves insoluble in water, may readily be obtained by making use of this reaction.

EXPERIMENT 84. Dissolve about 1 c.c. of the soap made in Experiment 82 in about 10 c.c. of hot water. Cool the liquid under the tap, and add about 2 c.c. of strong hydrochloric acid. A white precipitate will form. This is the stearic acid.

$$\left.\begin{array}{c}\text{Sodium stearate}\\+\\\text{hydrogen chloride}\end{array}\right\}=\left\{\begin{array}{l}\text{sodium chloride}\\\qquad+\\\text{hydrogen stearate.}\end{array}\right.$$

79. The explanation of the undoubted excellence of soap as a detergent (= cleansing material) has

received much attention at the hands of chemists, but the nature of the action or actions involved is complicated, and no simple statement can be made which will cover all the phenomena observed. At an early date it was found that water had the power of reacting with soap, acid soaps being formed which were comparatively insoluble, and a small amount of free alkali being left in the solution.

$$\left.\begin{array}{c}\text{Sodium oleate}\\ +\\ \text{hydrogen hydroxide}\\ \text{(water)}\end{array}\right\} = \left\{\begin{array}{c}\text{sodium hydrogen oleate}\\ +\\ \text{sodium hydroxide.}\end{array}\right.$$

Since alkalis attack grease with the formation of soaps, it was thought that the grease with which the dirt was accompanied was saponified (made into soap) by the free alkali and that the cleansing power of soap was partly due to this reaction. It has been shown, however, that alkalis of the strength which would be formed by the above reaction are much too weak to exert appreciable powers as saponifying agents. Even weak alkalis, however, have another effect upon grease, if the latter be of vegetable or animal origin. This effect may well be shown by a simple experiment.

EXPERIMENT 85. Pour about 1 c.c. of olive oil into a test-tube, add about 10 c.c. of water, and cork the tube. Shake the tube and its contents vigorously for half a minute. Put on one side in an upright position. Treat another similar quantity of olive oil with 10 c.c. of a solution of washing-soda, containing one per cent of soda. Repeat the above operations, substituting 1 c.c. of paraffin oil for the olive oil.

Compare the effects produced with those obtained when one per cent solution of borax (sodium borate) is substituted for the washing-soda solution.

It will be found that water alone is unable to retain much of the oils in suspension. The latter separate out readily, forming a distinct layer on top of the water. The olive oil treated with soda or borax does not thus separate out, but remains suspended in the liquid for a considerable time in the form of fine globules. Paraffin oil, however, is not affected in this way by the alkaline salts added. The soda and borax, in common with other alkalis and alkaline salts, are said to emulsify the fatty matter. Mineral oils are not capable of emulsification in this way. Emulsification would seem to depend upon the presence of a saponifiable fat, and other fats are kept in suspension longer when animal or vegetable fat is also present.

Experiment 86. Repeat the previous experiment, using a mixture of 1 c.c. of paraffin with 0·5 c.c. of olive oil in the place of the olive oil alone. Note the behaviour of the liquid after vigorous shaking, comparing it with the behaviour of paraffin oil when shaken with soda.

The emulsifying power of alkalis may be supposed to be of service in the removal of dirt by soap in that the small amount of free alkali formed in weak soap solutions will help to clean dirty linen or dirty hands by emulsifying the grease associated with the dirt, the latter being carried away attached to some of the small fat globules, or, freed from grease by the action of the alkali, may be more easily removed mechanically by the action of moving water.

The saponifying and emulsifying of grease by soap were long considered to be the main factors in cleansing with that material. Recently, however, Professor Herbert Jackson has shown that another property of soap solutions is brought into play. Examination of the behaviour of microscopical particles of dirt suspended in water shows that they are in a state of continuous movement, the smaller the particle the more rapid being the rate of motion. This was known as the "Brownian movement" of small particles, after Dr Brown, who first pointed it out. It is also termed *pedesis*, from a Greek verb meaning "to dart about". It is supposed that the movement is caused by the bombardment of the particles by the molecules of the liquid, which, it will be remembered, are themselves in a condition of rapid and continuous movement. (See Part I, Chapter v.) The smaller the particle, the more it will be affected by this molecular bombardment. Professor Jackson has shown that soap solution assists in loosening the attachment of small particles of dirt from dirty materials and thus allows pedesis to come into play, with the result that the small particles begin to move about freely with an oscillatory motion and are rendered capable of being carried away with the moving water.

An interesting point concerning pedesis is that the presence of many substances in solution in water has the effect of hindering the movements of the particles. Among these substances are alkalis, such as caustic soda and caustic potash, and alkaline salts, such as washing-soda. Hence it would seem that the presence of any considerable portion of free alkali in washing water is to be deprecated, and the quantity of washing-soda used for washing should be limited to little more than the amount necessary for softening the water.

80. Soap powders are frequently made use of for washing clothes. Such powders generally consist of powdered soap, together with varying amounts of washing-soda or other form of sodium carbonate, a certain proportion of insoluble matter, and some 40 per cent of water, the last named being chiefly held in combination with the various constituents. The value of these powders is somewhat doubtful, in view of what has just been said with reference to the effect of the presence of free alkali in retarding the removal of dirt by virtue of the Brownian movement. Probably the chief practical advantage arising from the use of soap powders is to be found in their easy solubility. In general it may be taken that the best results may be obtained by the use of a good soap and soft water, any alkali used to soften the water being added with discretion.

81. A point of importance in household finance is to obtain a soap which shall contain as large a percentage as possible of soluble soap and as little water and foreign matter as is feasible.

Experiment 87. Weigh out 5 g. of soap into a small porcelain dish, previously cleaned and weighed. Place the dish on a sheet of wire gauze over a *small* flame. To facilitate drying, the soap may be shredded after weighing. Heat the dish and contents, stirring from time to time with a clean glass rod, until moisture ceases to be deposited upon the under-surface of a clock-glass placed at intervals upon the top of the dish. Cool and weigh the dish as soon as cold. Check the completion of the drying by heating again for a short time, cooling and again weighing. Care must be taken to heat gently or the soap will be charred and the loss of weight will represent loss by decomposition of the soap as well as by evaporation of the water which is contained in it. Calculate the percentage of water. This should be from 20 to 30 per cent in the case of a good soap. Should the amount considerably exceed 30 per cent, the soap-maker is evidently making extra profit by selling water at the price of soap.

Dissolve 10 g. of the soap in 250 c.c. of distilled water. The solution should be almost clear, only a slight opalescence being perceptible. Allow the solution to stand for some time and examine the base of the containing vessel for sediment. A good soap should deposit no insoluble solid matter, or at most, so little that it may be neglected in estimating the value of the soap for laundry purposes.

82. It frequently happens in laundry work that dirt has to be removed which is more closely allied to the fabric than is the ordinary dirt removable by the use of soap and water. Stains of fruit juices, ink, acid, and old grease marks need the application of special methods of removal. One of the commonest stains is that produced by the use of soap and soda themselves in the process of washing. Alkalis cause a yellowish coloration in fabrics made of linen or cotton materials. To regain whiteness, the washed fabric is dipped into a liquid containing a material which, either in solution or suspension, causes the liquid to have a blue tint. The fabric is tinted faintly blue by this means and the blue colour neutralises the tint produced by the alkali. Several forms of "blue" are on the market. Among

them may be mentioned ultramarine—the artificial, not the natural, product—Prussian blue, indigo, and blues obtained from aniline. The latter are used in the liquid form, methylene blue being an example. The others are usually put up as solids.

The liquid blues of the aniline series combine with cellulose—the chemical name for the cotton and linen fibres—and their use is not recommended from this standpoint. Of the solid blues, Prussian blue contains iron, and during use or in later washing some of the iron may be deposited as the familiar "iron-mould". Indigo is said to leave a greenish tinge after use, and the best results may in general be obtained with ultramarine.

EXPERIMENT 88. Test the suitability for laundry purposes of as many different specimens of blues as can be obtained by the following method:

Make a "blueing-water" of about the depth of tint generally used in the laundry. Half fill each of 4 test-tubes with this liquid.

(*a*) Pour the contents of one test-tube through a filter-paper, fitted in a glass funnel in the usual way, into a clean test-tube. Note whether a residue remains upon the paper, or whether the paper is stained where wetted, and also examine the depth of tint of the filtrate, comparing it with that of the unfiltered liquid in another test-tube. Entire absence of colour denotes a blue of which the particles are held in suspension and are too coarse for efficient blueing. Partial loss of colour shows finer particles in suspension. In this case fold two filter-papers separately and insert both in a funnel so that three thicknesses of the upper paper rest upon one thickness of the lower and vice versa. Filter the liquid a second time through the filter thus arranged. It will probably be found that the filtrate possesses very little colour.

Should the liquid obtained after the first filtration be as strongly coloured as the original liquid, the blue is in solution. Examination of the filter-paper will usually show staining—evidence that such a blue is of the nature of a dye, and is not very suitable for general laundry use.

(*b*) In the liquid in a second test-tube immerse a small piece of cotton fabric which has been recently washed in strong soda solution and then thoroughly rinsed. Allow the cloth to remain in the liquid about a minute. Remove it and squeeze out as much of the water as possible. Dry it near a window, hastening the drying by opening it out as fully as possible and suspending it over a sand-bath heated by a small Bunsen flame.

When quite dry, compare the colour with that of a piece of similar cloth that has not been washed and with that of a piece that has been washed with soda and rinsed, but not blued. The nearer the tint of the tested portion approaches that of the unwashed specimen, the better the results that may be expected in actual practice.

(*c*) To the contents of another test-tube add about 2 c.c. of a solution of washing-soda, containing 1 g. of soda in 100 c.c., and boil the resulting liquid. Carefully examine the colour after boiling and note whether any residue is deposited on standing. Change of tint or the formation of a precipitate indicate blues of unsatisfactory character.

(*d*) Treat a fourth sample as in (*c*), substituting 1 per cent solution of caustic soda for the washing-soda solution. Examine as before.

The tests outlined above should each be performed with samples of all the blues and the results obtained in each test compared. From the examination of all the results, a general inference may be drawn as to the most suitable of the blues for the use of the laundress.

83. Stains due to the presence of vegetable colouring matter, such as those of writing ink, jam, fruits, tea and coffee, may be removed by the *cautious* application of a bleaching agent. In the preceding chapter it was shown that chlorine is capable of removing the colour from vegetable dyes. It may be made use of for bleaching stained goods, if care be taken to use weak solutions, and the fabric be thoroughly rinsed after bleaching is complete.

EXPERIMENT 89. Make a strong solution of acetic acid by dissolving about 20 g. of the glacial acid in 100 c.c. of water. To about 100 c.c. of water add about 5 g. of bleaching powder and boil till the liquid acquires a pinkish hue. Cool, add about 50 c.c. of water, and stopper well.

These solutions may be used to remove stains as follows:

Soak the stained portion of the material—say a piece of white rag on which a spot of ink has been made and allowed to dry thoroughly—with the acid solution. Remove superfluous moisture with a piece of clean blotting-paper and soak well with the bleaching solution. Allow the latter to remain in contact with the stain for a couple of minutes and then rinse thoroughly. If this treatment has not been sufficient to bleach the stain completely, repeat the soakings until success is attained. *Always* rinse carefully in several changes of water after using this bleaching mixture.

Grease stains are often troublesome to remove. If physical methods—such as the application of a warm flat-iron over the stain, previously covered with a thin layer of fuller's earth or two or three thicknesses of clean blotting-paper—fail to remove it, a solvent should be used in the manner directed in par. 76. Petrol, benzene and ether are the most efficacious solvents of general application. Great care must be exercised in their use on account of their great volatility and the very inflammable character of the vapours arising from them. It is best in all cases to make use of them in the open air, if possible, rather than in a closed room. Should such a solvent not be available, the grease may sometimes be removed by the application of an alkaline solution. Ammonia solution is preferable to the stronger alkalis for this purpose on account of its use being attended with less danger to the material of the fabric.

Paint and varnish stains should be treated with turpentine or benzene, but turpentine should not be used for delicate fabrics nor for cleaning silk. A mixture of two parts of methylated spirit with one part benzene is also a good paint remover. In all cases the application of several small successive quantities of the cleanser will be found more efficacious than the use of large amounts, which may cause the stain to spread and render its final removal a very troublesome matter.

Iron-mould, being a stain of a basic character, requires an acid to be used for its removal. Oxalic acid is most suitable for the purpose, and should be used warm in a solution of about 10 per cent strength. Repetition of the treatment, followed by thorough rinsing, will be necessary for the complete removal of strongly coloured stains of this nature.

84. In the preceding chapter, the bleaching action of chlorine was shown to be of the nature of an oxidation. In sulphur dioxide solution, or sulphurous acid, we have a bleaching agent, the action of which depends upon a reaction of the reverse character. The solution may be made by passing sulphur dioxide—the gas produced by burning sulphur—into water or by adding to a solution of sodium sulphite sufficient sulphuric acid to combine with the sodium present.

Experiment 90. Dissolve 10 g. of sodium sulphite in 100 c.c. of water and add 2 c.c. of strong sulphuric acid. Mix thoroughly. Smell the liquid cautiously, when the familiar odour of burning sulphur will be noted.

The bleaching powers of this liquid may be demonstrated by dipping a bunch of blue violets or other coloured flowers in season into it. The colour of the flowers will be rapidly discharged.

Equations:

$$\left.\begin{array}{c}\text{Sodium sulphite}\\ +\\ \text{hydrogen sulphate}\end{array}\right\} = \left\{\begin{array}{c}\text{hydrogen sulphite}\\ \text{(sulphurous acid)}\\ +\\ \text{sodium sulphate.}\end{array}\right.$$

$$\left.\begin{array}{c}\text{Hydrogen sulphite}\\ +\\ \text{oxygen}\end{array}\right\} = \text{hydrogen sulphate.}$$

The second equation represents the chemical change involved in the bleaching. The oxygen is supplied by the colouring matter, which is said to be "reduced", and the new product is usually colourless or very faintly coloured.

The sulphuric acid shown as being produced by the oxidation of the sulphurous acid must be very carefully removed from any fabric treated by this means, since, if left in contact with it, and allowed to become concentrated during the drying of the material, it will soon destroy the fibres completely. Its removal may be effected by rinsing in weak sodium carbonate solution, followed by thorough rinsing with plain water.

EXPERIMENT 91. The danger attendant upon incomplete removal of the sulphuric acid may be illustrated by dropping one drop of the diluted acid (one part of strong acid to 20 parts of water) on a piece of filter-paper. Dry the wetted portion by holding the paper over a small Bunsen flame. A black spot will be left as a result. This consists of the carbon contained in that portion of the paper which was wetted with the acid. Push the finger gently against the spot and it will be found that the whole of the carbonised portion may readily be removed.

Similar tests may be performed with small pieces of cotton and linen fabrics.

Sulphurous acid is more suitable for use with woollen and silk goods than is chlorine, which readily attacks these materials. Great care is necessary, however, in order to achieve successful bleaching of wool and silk.

A method in which alternate oxidation and reduction takes places is sometimes of value, especially for bleaching linen. The article to be bleached is first steeped in a solution of potassium permanganate of about one per cent strength until the stain has assumed a deep brown tint. This tint is caused by the deposition of manganese hydroxide from the permanganate by the action of the stain, which is oxidised by the oxygen rendered available at the same time. To remove the brown colour, the article may be next steeped in a sulphurous acid solution which combines with part of the oxygen of the manganese hydroxide, forming sulphuric acid, and this latter substance then dissolves the lower hydroxide formed, manganese sulphate, which in solution is practically colourless, being produced.

The place of the sulphurous acid may be taken by a solution of oxalic acid or of hydrogen peroxide. This latter substance, which is composed of the same elements as water, is readily changed into water and oxygen. It is itself a valuable bleaching agent, and is especially useful in cases where the production of strong acid substances, such as sulphuric or hydrochloric acid, cannot be tolerated on account of their corrosive effect. It is used in alkaline solution for bleaching hair and teeth. For use after potassium permanganate solution, it should be acidified with a little acetic acid and used instead of sulphurous acid to remove the hydroxide stain, manganese acetate being formed in this case.

As an exercise in the use of bleaching agents, a straw hat, which has become brown with age, may be treated.

Experiment 92. First clean the straw with soap and water, to which a little washing-soda has been added. Use as little liquid as possible and rinse by repeated wiping with a cloth wetted with water only. The straw will probably have gained a deep yellowish hue as a result of this treatment. Pour a small quantity of a solution of sulphurous acid over the straw and allow it to remain until no further bleaching effect can be discerned. Rinse as before. If the hat be now carefully dried, preferably in sunlight in the open air, the straw will have an almost white colour. To obtain a purer white, a second bleaching may be performed. Make a solution of hydrogen peroxide of about "three volume" strength by diluting some ten volume solution with twice its bulk of water. Pour a little over the straw and, after it has apparently attained its full effect, rinse and dry as before. The straw will have assumed a good white appearance, unless it was in a very bad condition at first. Repetition of the treatment will complete the bleaching even in very bad cases.

85. The action of alkalis upon the various materials used for clothing is of importance. Cotton and linen are derived from vegetable sources and consist almost entirely of fibres of cellulose, the material of which the walls of vegetable cells are composed. This is capable of offering considerable resistance to the action of alkalis without suffering disintegration.

EXPERIMENT 93. Into a beaker put two pieces of cotton and linen fabrics. Half fill the vessel with a solution of caustic soda, containing 10 per cent of solid alkali. Heat the liquid to boiling-point, and allow boiling to continue for about five minutes. On rinsing and examining the materials after this treatment, they will be found to be practically unaltered, as far as can be discovered by the naked eye.

Wool and silk are of animal origin and are very readily attacked by alkaline solutions, wool being especially sensitive.

Experiment 94. Into a beaker half full of 10 per cent caustic soda solution place pieces of a woollen and a silk fabric. Boil as in the previous experiment. It will be found that the woollen material will be completely dissolved by this treatment, while the silk will also be very considerably affected, although probably it will not be entirely dissolved.

Solutions of such strengths as those used above do not, of course, find any application in the ordinary household washing process. The experiments are only intended to illustrate the effects which may be expected if careless addition of alkaline substances be made in washing fabrics. The action of washing-soda and borax is less pronounced than that of the caustic alkalis, but goods washed with their assistance require thorough rinsing, or the alkaline liquid left in contact with the fabric is concentrated by drying, and ruinous effects may follow, especially if the articles thus treated are subsequently heated to a high temperature during the process of ironing.

In general, the use of alkalis is to be deprecated. If they are used, washing-soda in small quantities may be used for cotton and linen, while borax has perhaps the least harmful effect upon wool and silk.

Experiment 95. Select two pieces of the same thin woollen material. Test the action of sodium carbonate upon one piece of the material by immersing it in a solution containing 1 g. of washing-soda in 100 c.c. of water. Boil for five minutes, rinse well, and thoroughly dry. Again immerse in the boiling solution, rinse and dry as before. Repeat this process from 10 to 20 times.

Treat the other piece similarly, using a solution of borax containing 1·25 g. of the salt in 100 c.c. This solution is roughly equivalent chemically to the solution of washing-soda used previously.

Compare the appearance of the two pieces of material after they have undergone the same number of treatments in each case. If possible, examine a few fibres of the original material, and of each of the two pieces dealt with, under the microscope, using a magnification of not less than 100 diameters. The effects of the repeated treatment with weak alkalis upon the material will be thus rendered more clearly evident.

86. The student should become familiar with the appearance under the microscope of the various fabrics used as clothing materials. Assistance in recognizing them may be afforded by examination of the subjoined figures but this should in no case be considered as a sufficient substitute for actual work with the microscope itself.

Fig. 51 shows the general appearance of a fibre of wool when highly magnified. The toothed nature of the edge of the fibre should be noted, caused by the overlapping of the fine scales on its surface. The "felting" of wool which is rubbed too vigorously when washed is due to the shrinkage of the fibres and to the close interlocking of the fibres by their serrated edges. (Felt itself consists of woollen fibres which have been caused to interlock in this way by wetting and beating.) In woollen material that has been washed with alkalis, the fibres will be seen to have become partially disintegrated when examined microscopically. (Cf. result of Experiment 95.)

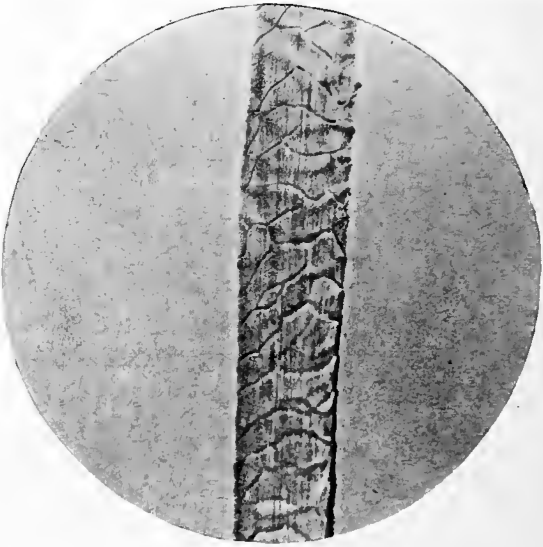

Fig. 51. × 320.

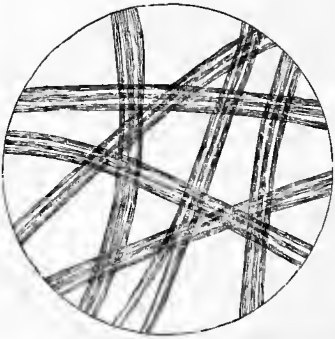

Fig. 52. × 160.

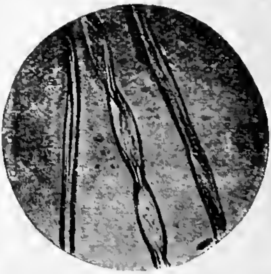

Fig. 53. × 110.

In Fig. 52 the microscopic appearance of silk fibres is illustrated. They present no differentiation of structure like that of wool and are finer than wool fibres. Silk has a glassy appearance when viewed on the stage of a microscope.

Fig. 53 represents highly magnified cotton fibres. They are stouter than silk and flattened so that they appear like small ribbons which have been twisted upon themselves. The latter peculiarity renders them very readily recognizable.

Linen (or flax) fibres differ from cotton in being rounded instead of flattened. They may be distinguished from the rounded fibres of silk by presenting longitudinal and transverse markings. The latter occur at fairly regular intervals and represent the limits of the various cells which go to make up a single fibre. Fig. 54 shows some strands of linen strongly magnified.

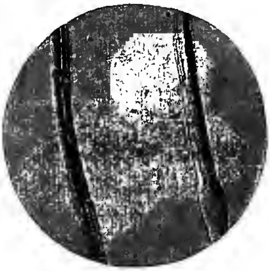
Fig. 54. ×110.

Experiment 96. Examine threads of each of the above materials under a high power of the microscope. The threads should be teased out with two needles in a drop of water on a slide in order to separate the individual fibres, and a clean cover glass placed over the drop. Make a careful drawing of what is actually seen in each case, without reference to the figures given above. Different specimens of the same material will be found to vary slightly in appearance when examined in this way, but a little practice should enable a careful observer to recognize any given material without difficulty.

Many samples of cloth consist of wool and cotton interwoven with one another. As an exercise in the work previously done, the following experiment, in which the percentage weights of wool and cloth in such a material are approximately determined, may be performed.

EXPERIMENT 97. Examine pieces of various cloths under the microscope until one is found which affords evidence of being composed of woollen and cotton fibres.

Weigh out about 5 g. of the material on a balance weighing to 0·01 g. If the fabric is new and unwashed, remove any dressing which may be present as completely as possible by repeated wringing out in cold water. Dry the wetted material on a clock-glass or in a porcelain dish in a steam or hot-water oven. When apparently dry weigh, after cooling, and replace in the oven. After 10 minutes, cool and reweigh. If no further loss of weight is noted, the material may be considered as properly dried. Note carefully the weight after the removal of the dressing.

Treat the fabric with 10 per cent soda solution as in Experiments 93 and 94. After boiling the solution for 5 minutes, pour away the liquid and soak the residue of the cloth in successive quantities of cold water, with frequent squeezing, until the water no longer turns a red litmus paper blue. Remove as much moisture as possible by squeezing and then dry the residue thoroughly as previously described till of constant weight. The residue is of course that portion of the original cloth which was made from cotton fibres.

The relative percentages of wool and cotton may readily be calculated as in the example below.

| | |
|---|---|
| Weight of original sample ... ... ... | 5·04 g. |
| ,, after removing dressing ... ... | 4·81 g. |
| ,, of dried residue (cotton) ... ... | 1·16 g. |

Hence weight of wool = 4·81 − 1·16 = 3·65 g.

$$\text{Percentage of wool} = \frac{3{\cdot}65 \times 100}{4{\cdot}81} = \mathbf{76.}$$

$$\text{,, \quad ,, \quad cotton} = 100 - 76 = \mathbf{24.}$$

Check the result thus obtained by making a similar determination, using another sample of the same material. Differences in the result of less than 2 per cent may be neglected, but, should greater variations be noted, a third and, if necessary, a fourth estimation should be made.

87. The treatment of the subject of cleansing and of the allied matter of bleaching, as given in this chapter, is far from exhaustive. Sufficient has probably been mentioned to give the thoughtful student hints as to the best way of attacking difficulties that may crop up in practice and to devise other simple experiments, upon the lines of those already done, to illustrate any part of the subject of especial interest.

The use of many of the substances dealt with in this chapter for purposes of disinfection will be postponed until a brief outline of the causes of infection has been given later.

## QUESTIONS

1. What products are formed by boiling fat with caustic soda, and how are they separated from one another?

2. What is the cause of the curd which is formed when soap is used with hard water?

3. Explain the effect of adding vinegar or other acid to a solution of soap.

4. Give a brief description of the various points involved in the explanation of the cleansing action of soap.

5. What chemical reactions take place during bleaching by means of sulphur dioxide, chlorine, and hydrogen peroxide? Give equations.

6. Describe clearly how you would attempt to remove blackberry stains from a child's pinafore. Give reasons for the method of treatment adopted.

7. How may an ink-stain be best removed from a linen collar?

8. Certain forms of soap contain finely divided powders, such as sand. Of what value do you consider the addition of such ingredients, and for what purposes would such a soap be suitable?

9. Mention three solvents for grease, and describe how any one of them may be made use of for eradicating a gravy stain from a woollen skirt. State any precautions you would adopt.

10. The acid soaps formed in weak soap solutions sometimes leave stains in the fabrics washed. Suggest any method of preventing the formation of such acid soaps.

11. Outline the method you would adopt to ascertain the suitability for its purpose of a much advertised laundry blue newly put on the market.

12. A material described as "all wool" is under suspicion on account of its cheapness. By what tests may the truthfulness or otherwise of its description be determined?

# CHAPTER VIII

## STARCH; ITS NATURE AND CHIEF DERIVATIVES

88. From the roots, stems, or fruits of many and various plants a white powder may be readily separated by the process known as "maceration". This white powder is starch, and the method of obtaining it may be illustrated by the following experiment.

Experiment 98. Place a few grams of wheaten flour in a small porcelain dish. Add small quantities of water from time to time, stirring the mass well with a glass rod or spatula after each addition. Continue this until a "dough" is formed, *i.e.* till the flour and water have formed an intimate mixture which is coherent but does not stick to the fingers. Put this lump of dough in the centre of a piece of fine muslin. Bring the corners of the muslin together around the dough, and tie them securely so as to form a small bag. Knead the bag firmly with the fingers under a small quantity of water in a basin. The water soon becomes somewhat milky in appearance.

After a few minutes pour off the water into another vessel, and further knead the dough with a fresh supply of water. When, after changing the water as before, the new supply is not rendered appreciably milky by the kneading, this latter operation may be stopped. Pour all the water used into one vessel and allow it to stand for some time. A white powder slowly settles on the bottom of the vessel. This powder is wheat starch. When most of the starch has settled, decant away the water, remove the starch to a small porcelain dish and dry it carefully in a hot-water oven.

The starch thus obtained appears to the naked eye as a white and somewhat irregular solid lump. This lump is readily crushed to a fine powder which usually has a somewhat glistening appearance.

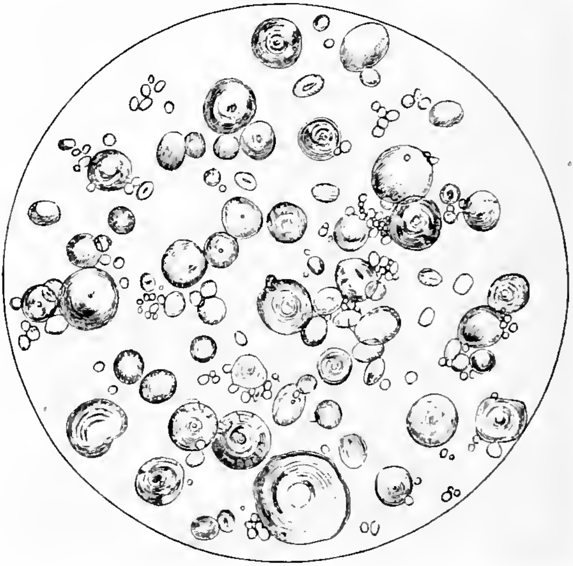

Fig. 55. Wheat starch. × 320.

To examine further the external characters of this powder, the use of a microscope is necessary.

Experiment 99. Put a drop of water on the centre of a clean glass slide. Dip the point of a penknife in the powdered wheat starch prepared in Experiment 98, and touch the water with the knife point. Cover the milky liquid thus produced with a thin glass cover-slip. Put the slide thus prepared on the stage of a microscope. Using an objective of low magnifying power (say the one-inch), arrange the slide so that a group of the small particles of starch is focused in the centre of the field of view. Now remove the low-power objective, and substitute one with a focal length of $\frac{1}{4}''$ or $\frac{1}{6}''$. Adjust the instrument with the face of the objective nearly touching the surface of the cover-slip. Slowly raise the tube till the starch particles come into view. Focus carefully with the fine adjustment, and note the peculiar appearance of the exterior of each separate granule. (See Fig. 55.)

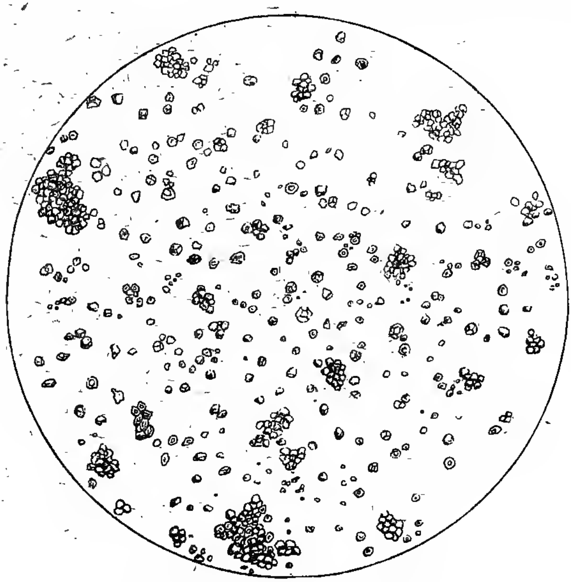

Fig. 56. Rice starch. × 320.

Similarly examine some laundry starch, of which the best is made from rice, some potato starch—obtained by scraping the surface of a freshly cut potato, and dropping a little of the milky fluid thus formed on a glass slide—and a sample of American cornflour, which consists almost entirely of maize starch. (The general appearance of these starches is indicated in Figs. 56, 57, and 58.)

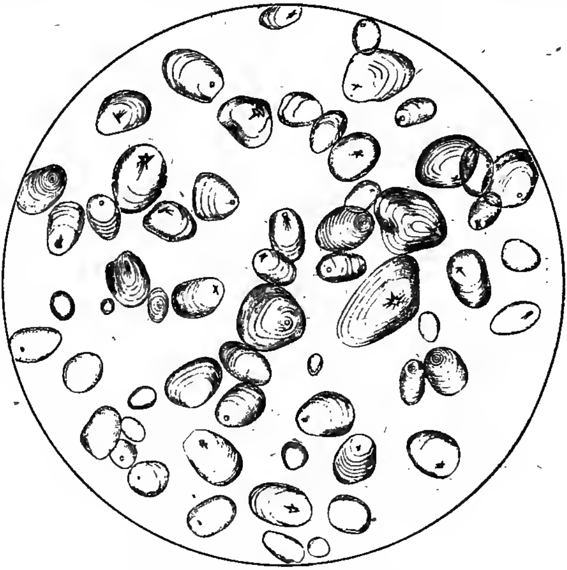

**Fig. 57. Potato starch. × 250.**

If only a low power objective be available, it is useless to attempt to examine the structure of the wheat and rice starches, but the granules of the potato starch are sufficiently large that a fair idea of their appearance may be obtained even with a low power.

It will be seen that starch differs completely in the structure of its particles from bodies which we have previously considered. Its particles are neither crystalline nor amorphous, as are the smallest particles of such bodies as the oxides and salts previously dealt with. The starch granule has a peculiar "layered" or "striated" structure, which is probably due to the method of its deposition within the tissues of the living plant.

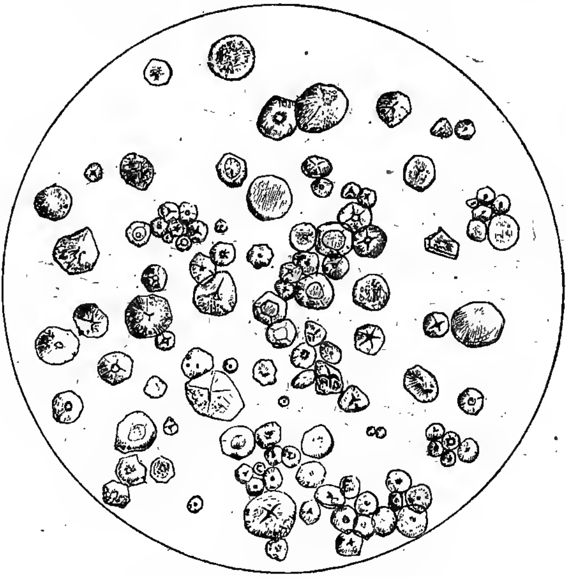

Fig. 58. Maize starch. × 350.

Starch is prepared on the manufacturing scale by breaking and bruising starch-containing seeds or roots in a large tank through which a constant stream of water runs. The starch particles settle to the bottom of the tank, while the husks and fragments of cellular tissue, being less dense, float away in the stream of water.

89. Starch is, chemically speaking, a very complex body. It is, however, a chemical compound, and contains three elements only.

Experiment 100. Heat a little starch in a porcelain dish over a Bunsen flame. Watch the changes in colour produced as the temperature of the starch rises. After the heating has continued for some time, the starch is blackened or charred; and if the heating be sufficiently strong and prolonged, the starch burns completely away.

"Charring" is a sign of the presence of carbon, and this element may be shown to be present in many substances by means of this very simple test.

Experiment 101. Repeat Experiment 100, substituting the following bodies in turn for the starch:

(*a*) a piece of paper;
(*b*) a few bread crumbs;
(*c*) a small piece of woollen cloth;
(*d*) a small lump of dry cheese.

From the observations made, determine whether these bodies contain carbon or not.

A more decisive test, and one that is applicable to compounds of carbon which do not char on heating, is that described in

Experiment 102. Dry about 5 g. of powdered copper oxide by spreading it in a thin layer over the bottom of a porcelain dish, and heating it for some minutes with a strong Bunsen flame. Put about one-twentieth of this dried oxide in a mortar, and thoroughly mix with it an equal amount of dried powdered starch. Transfer this mixture to the bottom of a small hard glass tube. Put the rest of the dried oxide into the tube so that it forms a layer above the mixture.

Fit this tube with a cork and bulbed delivery tube as in Fig. 59. Place a small quantity of *dried* powdered copper sulphate in the bulb, and allow the end of the delivery tube to dip under the surface of lime-water in the beaker. Heat the tube with a good Bunsen flame, beginning the heating at the end of the powder nearest the mouth of the tube, and very slowly move the burner along till the end of the tube containing the starch is reached. Strongly heat this for a few minutes and note the behaviour of the lime-water and of the anhydrous copper sulphate. Examine also the appearance of the powder at the bottom of the tube.

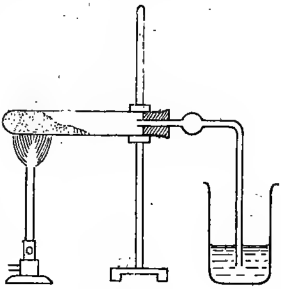

Fig. 59.

From the observations made it will be evident that carbon dioxide and water are produced. Now copper oxide contains neither carbon nor hydrogen. Hence the carbon and hydrogen required to form the carbon dioxide and water respectively must have come from the starch, while the copper oxide supplies some of the oxygen required to convert the carbon and hydrogen into their oxides as shown by the appearance of reddish-brown particles of copper at the bottom of the tube.

An elaboration of the above method of "combustion", as it is termed, with copper oxide, is used in estimating the exact quantities of carbon and hydrogen present in bodies containing them.

The third element which is present in the starch is oxygen. No simple test is known, however, by which its presence may be directly shown.

When analysed carefully starch is found to have the following percentage composition by weight:

| | Per cent |
|---|---|
| Carbon ... ... ... ... | 44·4 |
| Hydrogen ... ... ... | 6·2 |
| Oxygen ... ... ... ... | 49·4 |

The ratio of the weight of hydrogen to that of oxygen is 6·2 : 49·4 or (very nearly) 1 : 8, and this being also the ratio of the weight of hydrogen to that of oxygen in water, starch is called a "carbohydrate", *i.e.* a complex compound of carbon with hydrogen and oxygen, the latter elements being present in the same ratio by weight as that in which they combine to form water.

(*Note.* A carbohydrate is *not* "a compound of carbon and *water*".)

Many other bodies besides starch contain carbon combined with hydrogen and oxygen, the last-named elements being present in the ratio 1 : 8 by weight, and these are all classed as carbohydrates. Some of the more important members of this class will be dealt with at a later stage.

90. We will next examine the properties of starch more fully.

EXPERIMENT 103. Make a weak solution of iodine by putting two or three small crystalline flakes of iodine and a crystal of potassium iodide into a test-tube half filled with water and shaking the liquid till the iodine has all dissolved. (The potassium iodide is used in order to make the iodine dissolve more readily and takes no recognizable part in the reactions which are to be performed with the iodine solution.) The colour of the solution obtained should be a pale brown, like that of rather weak tea. If it is darker than this, add more water. Preserve this solution for future use.

Pour a drop of iodine solution on some dry starch powder contained in a small porcelain dish. Note the bluish stain which is produced. This formation of a blue substance with iodine solution is the most delicate and characteristic test for starch. The composition of the blue compound is not known with certainty, but it is frequently spoken of as "iodide of starch".

EXPERIMENT 104. Put a little powdered starch with some cold water in a test-tube, and shake the tube vigorously for about a minute. Filter the liquid to remove suspended starch particles. Pour into the filtrate, which should be quite clear, a *few* drops of the iodine solution made in the last experiment, and note any coloration which may be produced.

EXPERIMENT 105. Grind about 2 g. of starch with a little water in a mortar till a thin paste is formed. Boil about 150 c.c. of water in a beaker, and pour the paste into the boiling water, stirring well all the time. Allow the water to continue boiling for about a minute, and note the character of the liquid obtained. This liquid is usually termed "starch paste". Keep it for use in further experiments.

Fill a test-tube one-third full with the starch paste just made. Cool the liquid by holding the closed end of the tube under a stream of water from the tap. When cold, pour in a *few* drops of iodine solution. Observe the coloration produced. Warm this liquid, noting any change of colour that occurs. When it reaches boiling-point, stop the heating and again cool the tube and contents with water from the tap.

From Experiment 104 it is clear that, since no blue coloration is obtained on adding the iodine solution, starch does not dissolve in cold water. On the other hand, from the production of the blue colour in Experiment 105, it would appear to do so in hot water. In the latter case, however, the reaction is not of so simple a character as that involved in dissolving such a substance as salt in water. The starch granules have an outer envelope ("starch-cellulose") which contains a jelly-like substance ("granulose"). Cold water does not affect either portion of the granule, but when the starch is treated with hot water, the granules swell up, the envelopes burst, and the contents are disseminated uniformly throughout the liquid, forming, according to the quantity of starch contained, a jelly-like solid or opalescent liquid, which holds in suspension the fragments of the burst envelopes.

EXPERIMENT 106. Put a drop of the starch paste made in the last experiment on a glass slide, and cover it with a cover-slip. Examine this slide with the microscope, using a high power objective, and compare the appearance of the preparation with that of the undissolved starch seen in Experiment 99.

EXPERIMENT 107. Plunge red and blue litmus papers separately into some starch paste.

Since no change of colour is to be noted in either case, starch paste is neither acid nor alkaline, but neutral in character.

Experiment 108. Make another beaker of starch paste by the method of Experiment 105, using about 10 g. of starch, and about the same volume of water as was used in that experiment. Allow the liquid to cool and examine its nature when cold.

The jelly-like character of the substance exuded from the starch-sacs under the influence of hot water is well shown by this experiment.

91. Starch may readily be transformed into other bodies of less complex composition and possessing properties quite distinct from those of the parent substance.

Experiment 109. To about 50 c.c. of the starch paste made in Experiment 105, add about 1 c.c. of dilute sulphuric acid, containing one part of acid to four of water.

(*Note.* Dilute nitric or dilute hydrochloric acid may be substituted for the sulphuric acid without affecting the final result of the experiment.)

Warm this mixture nearly to boiling-point in the water-bath. From time to time remove a few drops with a pipette or a piece of glass-tubing and test each sample thus taken, after cooling, with iodine solution. When the liquid gives no blue coloration, but only a reddish-brown, remove a larger sample and allow it to drop into some alcohol (strong spirit of wine) in a small beaker. Keep the remainder of the liquid for Experiment 111.

The white flocculent precipitate which separates out in the beaker is known as "dextrin" or "British gum". This body may also be formed from starch by the action of heat alone at a temperature of about 150° C., but the time required to effect the change is much longer than in the experiment just performed. When obtained by this latter method it is usually of a light cream-yellow colour. When bread is baked, some of the starch in the crust of the loaf is thus changed by the heat into dextrin.

Experiment 110. Put a little dextrin in a test-tube and shake it up with some water. It will be found that it differs from starch in being soluble to a considerable extent in cold water. The solution formed is sticky to the touch. Hence the name "British gum" is applied to commercial dextrin. Test the action of iodine solution on a little of the solution of dextrin.

Dextrin solution is sold for use as an adhesive, and is very commonly used as a backing for postage stamps and labels.

Although dextrin differs so considerably in its properties from starch, analysis shows that the former has the same percentage composition as the latter body. It is consequently a carbohydrate, but is probably less complex in internal chemical structure than is starch.

Experiment 111. Heat the remainder of the liquid prepared in Experiment 109 in the water-bath nearly to boiling-point for 15 to 20 minutes. Remove a sample, and test it with iodine solution.

It will most probably not give the reaction for either starch or dextrin. Should it, however, do so, heat again for five minutes and once more test with iodine solution. Repeat this heating and testing till no distinctive coloration is obtained but only the pale yellow due to the colour of the iodine solution itself.

The liquid now contains a second new substance produced by further action of the acid on the starch. To determine more exactly the nature of this change, let us try

EXPERIMENT 112. One-third fill a test-tube with the starch paste made in Experiment 105. Put an equal quantity of the liquid formed in the last experiment into another test-tube. To each add about 1 c.c. of strong caustic soda (or potash) solution, and about five drops of a solution of copper sulphate. Warm the contents of each tube, after shaking well, with a Bunsen flame. No special change will be noted in the appearance of the liquid containing the starch paste, but in the other test-tube a precipitate readily forms. This precipitate consists of a mixture of cuprous hydroxide, which is yellow in colour, with cuprous oxide, which is red, the proportions of these, and hence the colour of the precipitate produced, varying with the strengths of the various solutions used, and the time during which they are heated together.

The copper sulphate is said to be reduced, because the copper in it is changed from a higher state of oxidation to a lower. (See Chapter VII.) The production of this precipitate is due to the presence of a body termed "glucose", which is, like starch, a carbohydrate, but has the following composition by weight:

| | Per cent |
|---|---|
| Carbon ... ... ... ... | 40·00 |
| Hydrogen ... ... ... | 6·67 |
| Oxygen ... ... ... ... | 53·33 |

The percentage of carbon is lower than in starch, but the ratio of the weight of hydrogen to that of oxygen is still 1 : 8.

The change which occurs to the starch may be briefly represented thus:

Starch + water = glucose,

*i.e.* starch, when heated with dilute acids, combines with *the elements of water* to form glucose. The acid greatly assists the rate at which this reaction occurs, but does not enter into the composition of the resulting product. (Compare the action of manganese dioxide as described in Part I, Chapter xv.)

(*Note.* Instead of caustic soda and copper sulphate solutions, "Fehling's solution" may be used. This is made by adding tartaric acid or, better, Rochelle salt, *i.e.* sodium potassium tartrate, to copper sulphate solution and then caustic soda till the solution has a clear blue colour. It gives the best results when freshly made.)

If for the dilute acid of Experiment 109 extract of malt (made by crushing some malted barley with water) be substituted, the starch paste will quickly become more limpid, and a similar series of changes will occur. Dextrin is first formed, and is then converted into "maltose", a substance which resembles glucose in that it is a carbohydrate, and is capable of reducing alkaline copper solutions. Its percentage composition by weight is however:

| | Per cent |
|---|---|
| Carbon ... ... ... ... | 42·1 |
| Hydrogen ... ... ... | 6·43 |
| Oxygen ... ... ... ... | 51·47 |

Maltose and glucose will be further dealt with in the next chapter.

92. The properties of starch have been rather fully considered in the foregoing pages on account of the great importance of this substance as an article of diet. Much of our vegetable food consists of starch. The cereals, *e.g.* wheat, barley, rye, oats, maize, rice, and legumes, *e.g.* beans, peas, lentils, contain starch in amounts varying from 50 to nearly 90 per cent of their total weights. Potatoes also yield large quantities of starch. Many of the substances used in making puddings are simply prepared forms of starch, and may indeed be looked upon as almost pure starches, since the only other important constituent of most of them is water. Arrowroot, sago, tapioca, and cornflour (which may be either maize or rice starch) are examples of such prepared starches. It is easy to test these bodies by means of the "iodide of starch" test. It is sufficient in most cases merely to drop the solution of iodine on the substance to be tested for starch, although the test is more delicate, and the colour produced much finer, when the starch is in the form of starch paste. The latter should not contain much of the starch.

For further information on the question of starch as an article of diet see Chapter XI.

## QUESTIONS

1. Describe exactly what you understand by the term "carbohydrate". Name three substances belonging to this class.

2. Filter-paper consists of nearly pure "cellulose", which is a carbohydrate having the same percentage composition as starch.

How would you show that this substance contains both carbon and hydrogen?

3. Describe three chemical reactions by means of which you could show that a given white powder was starch.

4. By what experiments would you endeavour to show that the starches prepared from rice, maize, and potatoes are essentially one and the same chemical substance?

5. A white powder is stated to be a mixture of starch and salt. What tests would you employ to verify the presence of each of these substances in the powder, and how would you obtain a pure dry sample of each substance from the mixture?

6. What weight of carbon is contained in 28 lb. of starch? If all the hydrogen and oxygen in that weight of starch could be removed from it in the form of water, how many pints of that liquid would be obtained?

7. A pale bluish-white powder answers to the following tests:
   (*a*) When dissolved in water it forms a green solution.
   (*b*) When a few drops of this solution are heated with some maltose solution and a little caustic soda solution a reddish precipitate forms.

Name the powder.

# CHAPTER IX

## THE SUGARS

93. To the group of carbohydrates belongs a series of compounds known as "the sugars", in that many of them resemble ordinary sugar (cane sugar) in being more or less sweet to the taste. Two members of this series have already been mentioned. Glucose (dextrose, or grape sugar) was shown to be formed by the action of a dilute mineral acid on starch, and large quantities of glucose are manufactured by this

method for use in brewing and other industries. In conjunction with another sugar, laevulose (fruit sugar), it occurs in many fruits, especially grapes. The small sugary particles found in raisins and other dried fruits consist essentially of glucose. The small solid particles found in honey are small crystals of glucose.

Experiment 113. Put a small quantity of honey in a beaker. Add about twice its bulk of spirit of wine, and stir the mixture thoroughly for about two minutes. Carefully pour away the spirit, which contains in solution the more readily soluble syrupy portions of the honey. Small crystals of glucose, which is not very soluble in alcohol, will remain. Dissolve these in water and test the solution for glucose by the method of Experiment 112.

Maltose is also made on the large scale in the process of brewing by the action of a body called diastase found in the malted grain, which is said to be capable of converting about 2000 times its own weight of starch into maltose.

94. Two other sugars call for special attention, namely, cane sugar (sucrose, or saccharose)—obtained by expressing the juices from the stem of the sugar-cane or the root of the beet, clarifying the liquid thus obtained by filtration through animal charcoal, and allowing it to crystallise—and milk-sugar (lactose)—produced when the whey of milk is evaporated. Both these sugars have the same percentage composition as maltose (see Chapter VIII), but differ in properties from that sugar, and from each other.

Experiment 114. Taste specimens of cane and grape sugars, and note the difference in sweetness.

Cane sugar is usually considered to be much sweeter than the other.

Experiment 115. One-third fill a beaker with water, and heat the liquid to boiling-point. Drop in crystals of cane sugar till no more will dissolve, and then withdraw the source of heat. Note the quantity of sugar required to saturate the water and the nature of the solution produced. Keep this solution.

Repeat this experiment with glucose, and compare the quantities of cane and grape sugar required to saturate the same quantity of water.

Experiment 116. Test the solutions of cane and grape sugar made in the last experiment with red and blue litmus solutions. Like starch, these sugars will be found to possess neither acid nor alkaline reaction when in solution.

Cane sugar crystallises out from strong solutions in large hard clear crystals, which are known as sugar-candy. To obtain specimens of these crystals, perform the following experiment.

Experiment 117. Make some hot strong cane sugar solution as in Experiment 115. Tie a short length of fine string to the middle of a glass rod, and suspend the string in the hot solution. (See Fig. 60.) Allow the solution to cool down slowly, and note the character of the crystals which form on the string.

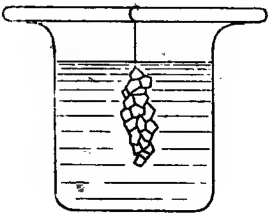

Fig. 60.

When cane sugar is carefully heated, either alone, or with a little water, a non-crystalline glassy substance known as "barley-sugar" is obtained.

EXPERIMENT 118. Half fill a porcelain dish with crystals of cane sugar, and add sufficient water to wet the crystals. Pour off any excess of water, and then heat the dish and its contents in a hot-air oven, the temperature of which is kept at from 150° to 160° C. When the sugar has melted, remove it from the oven and allow it to cool. Examine the nature of the substance obtained, and compare it with the sugar-candy made in the last experiment. Keep this barley-sugar, and note that after a time it becomes much less transparent. This is due to the formation of small crystals, the vitreous (glassy) modification of cane sugar not being a completely stable form.

Further careful heating results in the formation of burnt sugar or "caramel", which is used as a colouring matter for alcoholic liquors, sauces, and gravies.

EXPERIMENT 119. Heat some cane sugar carefully in a small porcelain dish over a Bunsen flame, continuing the heating beyond the melting-point. Note the change in colour that occurs, and the characteristic smell which is produced. The dark-brown sticky substance thus formed is caramel. Remove a portion for the next experiment. Heat the remainder strongly, and compare the behaviour of the strongly heated sugar with that of the starch in Experiment 100. Repeat this test with glucose in place of cane sugar.

It is probable that the brown exterior of well-baked or toasted bread consists partly of a substance resembling caramel to some extent, which has been produced by the action of heat on the starch in the flour (cp. p. 186).

EXPERIMENT 120. Dissolve a little of the caramel produced in the last experiment in some water in a test-tube. Toast a piece of bread till nearly black. Scrape off the outer portions, and shake the scrapings vigorously with a little water in another test-tube. Compare the appearance and taste of the two liquids thus obtained.

These brown solutions may be decolorised by the action of animal charcoal as described in Chapter v, Experiment 46. The crude sugar solutions expressed from the cane or the beet are of a brown colour, and are similarly decolorised by passage through filters of animal charcoal.

EXPERIMENT 121. Repeat Experiment 102, using (*a*) cane sugar, (*b*) grape sugar, instead of the starch.

Indications similar to those noted when starch was used will be obtained.

EXPERIMENT 122. Dilute a little of the cane sugar solution made in Experiment 115 with a considerable quantity of water. Test the action of this solution on an alkaline copper solution when boiled with the latter (*a*) for half a minute, (*b*) for several minutes, and compare your observations with those made in Experiment 112.

EXPERIMENT 123. To about 5 c.c. of the strong cane sugar solution of Experiment 115, add 100 c.c. of water, and about 2 c.c. of diluted sulphuric (or nitric or hydrochloric) acid. Heat the liquid for about half-an-hour in a flask fitted with an inverted condenser as in Fig. 61. By this arrangement, the steam produced is condensed, and drops back into the flask instead of escaping into the open air and thus causing the bulk of the solution to decrease.

(*Note.* Instead of the Liebig condenser shown, a long straight glass tube may be passed through the cork. This will not serve as well as the condenser, but will prevent some loss. Or the flask may be inserted in the water-bath in which its temperature will never reach the point at which vigorous ebullition, and consequent serious loss of liquid, will occur.)

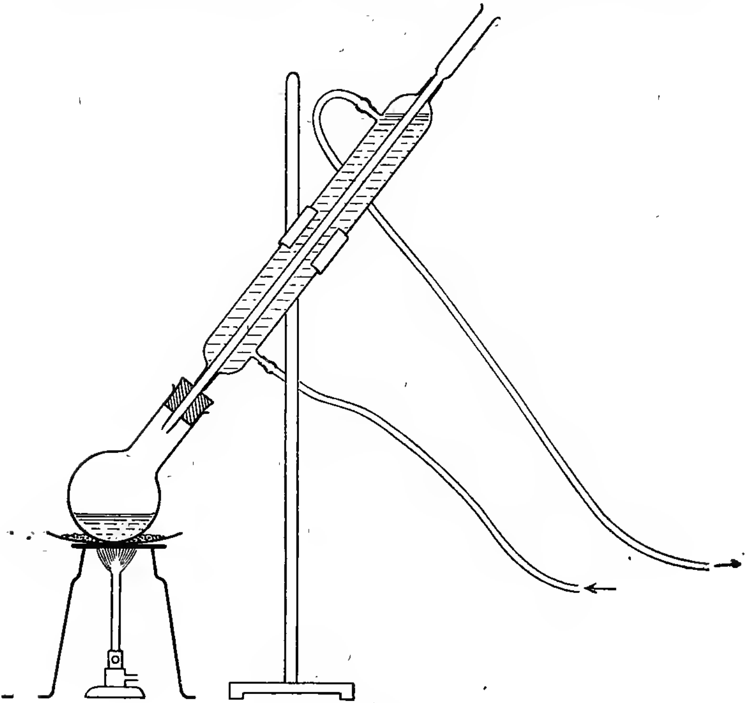

Fig. 61.

At the end of half-an-hour, remove a sample of the liquid from the flask, add caustic soda to this sample till it is distinctly alkaline, and then pour in a *few* drops of copper sulphate solution. On heating this mixture, a red precipitate of cuprous oxide will be obtained, showing the presence of a substance (or it may be substances) which behaves similarly in this respect to glucose. The reaction which occurs is of similar nature to that which takes place when starch is heated with a dilute acid, and may be briefly expressed thus:

Sucrose + water = dextrose + laevulose.

Equal quantities of the two latter sugars are produced.

95. Should a sufficient supply of lactose and maltose be available, the student should repeat Experiments 114, 115, 116, 119, 121, and 122, using these sugars instead of the cane or grape sugar.

It will be found that dextrose, lactose, and maltose all reduce Fehling's solution. To distinguish glucose from the others, the following test may be performed.

Experiment 124. Add 1 c.c. of glacial acetic acid to 100 c.c. of distilled water. In this weak solution of acetic acid, dissolve 4 or 5 grams of copper acetate. The liquid reagent thus formed is known as "Barfoed's solution".

To a small quantity of this reagent add a few drops of glucose solution. Boil the mixture. A red precipitate of cuprous oxide will be obtained.

Repeat this test with solutions of lactose and maltose respectively. It will be found that no reduction occurs in either case.

The reducing action of glucose may be further illustrated by the following interesting experiment.

Experiment 125. Fill a well-cleaned test-tube one-third full of distilled water. Add about six drops of ammonia solution, and then, drop by drop, a weak solution of silver nitrate, till the last drop produces a faint precipitate which does not disappear on shaking. Next add a few drops of glucose solution. Place the test-tube in a beaker of water (see Fig. 62) and heat the beaker till the water boils. If the directions given are carefully carried out, a brilliant deposit of metallic silver will be formed on the inside of the test-tube. The glucose has reduced the silver nitrate in the solution to metallic silver.

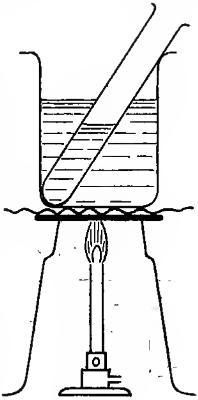

Fig. 62.

96. The results of all the above experiments, together with those obtained with starch and dextrin, should be tabulated carefully. A suggested form for this table is shown on the following page. The percentage composition of each compound should be shown in the table for purposes of comparison.

97. In the preceding chapter it was mentioned that starch was a very important foodstuff. It is rarely used as such, however, in the raw state, being then both practically indigestible and somewhat unpalatable.

Experiment 126. Tie tightly over the mouth of a thistle funnel a sheet of parchment paper. Into the funnel introduce by means of a pipette enough starch paste to fill the head of the funnel and a short portion of the neck. Immerse the funnel, head downwards, in a vessel containing pure water, in the manner shown in Fig. 63. Allow the apparatus to stand for three hours.

| | Starch | Dextrin | Dextrose | Maltose | Lactose | Sucrose |
|---|---|---|---|---|---|---|
| Taste | | | | | | |
| Solubility in water | | | | | | |
| Action of heat | | | | | | |
| Action of dilute acid | | | | | | |
| Action on litmus | | | | | | |
| Reaction with iodine solution | | | | | | |
| Reaction with Fehling's solution | | | | | | |
| Reaction with Barfoed's solution | | | | | | |
| Percentage composition | | | | | | |

Fit up a similar piece of apparatus, replacing the starch solution by one of glucose or by weak starch paste to which a few drops of extract of malt have been added. Allow this to stand for the same time as the first.

Note any alterations which occur in the levels of the solutions inside the thistle funnels. After standing, remove a sample of each liquid from the vessels which originally contained pure water. Test the sample in which the starch paste has been suspended with iodine solution, and try the effect of the sample from the other vessel on Fehling's solution.

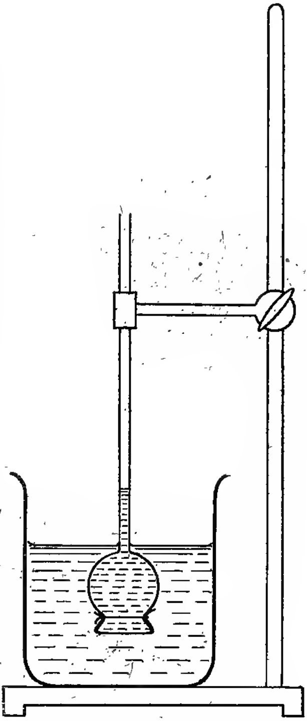

Fig. 63.

(Parchment paper suitable for the above experiment may be made as follows:

Immerse a large *dried* filter-paper for 20 seconds in some cold sulphuric acid (two volumes of acid to one of water). Remove the paper, place it quickly in a large vessel of water, and after a few seconds transfer it to another vessel containing a weak solution of ammonia, moving it about in the latter for half-a-minute. Dry carefully in the hot-air oven.)

It will be found that the starch does not pass through the parchment membrane into the water, while the sugar does so comparatively readily. This process is known as "dialysis" and the apparatus used in the above experiment is a simple form of "dialyser". Bodies which, when in solution, readily pass through such membranes as parchment paper are termed "crystalloids", while those to which such membranes are almost entirely impermeable are called "colloids". The membranes themselves are of a colloidal nature.

During the course of digestion, the various food substances, in order to be of value as food, must be capable of absorption by the cells lining the alimentary tract. These cells, which vary in character in different regions, are joined to form the lining membranes and, like the parchment paper, are not readily permeable by colloids. Much of our vegetable food, however, consists of starch, and this is a typical colloid. To change this to a sugar, and hence to render it of use as food, is a function of certain bodies found in the digestive juices. These bodies are members of the class of substances termed "ferments". In general, a ferment may be said to be a very complex substance, a small quantity of which is capable of effecting the chemical transformation of a relatively large quantity of some other substance into bodies of a simpler nature. The action on starch of one such ferment, diastase, has already been mentioned. Certain ferments found in the digestive juices, *e.g.* ptyalin in the saliva, and amylopsin in the pancreatic juice, are capable of acting on starch in a similar fashion to that of diastase. In order that the starch may be readily transformed, it should first be cooked, *i.e.* made into starch paste, although uncooked starch is acted upon to some extent by the stronger ferments, such as amylopsin. The following experiment illustrates the action of a body-ferment on starch.

Experiment 127. Make a little starch paste as in Experiment 105, and boil it for about five minutes. Put into each of two test-tubes a small quantity of this starch paste, and into a third about half a gram of dry starch together with a little cold water. To the third and to one of the other test-tubes add about 1 c.c. of saliva direct from the mouth, while to the remaining tube add an equal bulk of saliva which has been well boiled. (To increase the flow of saliva, the vapour of acetic acid may be gently inhaled through the mouth.) Put all three test-tubes into the same vessel of water (see Fig. 62) and heat the water to a temperature of about 37° C., *i.e.* to about the usual body-temperature. At intervals of five minutes, test small samples taken from the liquid in each test-tube with iodine solution. The liquid containing the boiled saliva gives the blue colour of iodide of starch repeatedly, while that containing the unboiled saliva and starch paste soon loses its power of reacting with the iodine solution. When this last liquid has quite ceased to react, add to it about 2 c.c. of caustic soda solution and five drops of a solution of copper sulphate. Boil the resulting liquid. A red precipitate indicates that maltose has been formed by the action of the ptyalin in the saliva upon the cooked starch.

Boiling the saliva destroys the ptyalin and hence the boiled saliva does not effect the change of the starch into maltose. The uncooked starch is unaffected by the saliva, and hence the liquid in this case gives no reaction with either iodine solution or an alkaline copper solution.

## QUESTIONS

1. Why is it a matter of importance that starchy foods should be well cooked?

2. A white powder is supplied to you. What tests would you employ in order to find out whether it was starch, cane sugar, or grape sugar, and what would be the result of each test you mention on each of these three substances?

3. What is "dialysis"? Describe a simple form of dialyser, and how it should be used in order to discover whether dextrin is a colloid or a crystalloid.

4. By analysis a certain substance is shown to contain 3·00 g. of carbon combined with 0·46 g. of hydrogen and 3·66 g. of oxygen. Name all the substances you know which have this composition, and suggest tests whereby the probable nature of the substance analysed may be discovered.

5. A liquid gives a blue colour with iodine solution, reduces Fehling's solution, and possesses very little taste. What substances would you suspect to be present in the liquid? How would you proceed in order to verify your suspicion?

6. Describe an experimental method of determining the comparative solubilities of maltose and lactose in water at 15° C.

7. You are supplied with a liquid which you are told consists of 100 c.c. of water in which a known weight of cane sugar has been dissolved by shaking, without the application of heat. Devise two distinct methods of discovering the weight of sugar which has been added to the water.

# CHAPTER X

## FERMENTATION. ALCOHOL AND THE VEGETABLE ACIDS

98. Among the earliest of chemical discoveries was the fact that, if a solution of honey or other sweet liquid were allowed to stand for some days in the open air, the character of the liquid was greatly changed. It frothed to some extent, lost its sweet taste and gained intoxicating properties. At a later date, it was found that the addition of certain substances to the solution had the effect of hastening the change very considerably, the most prominent among these bodies being yeast. This and most of the other substances used to hasten the change belong to the lowly class of plants called "Fungi", and are among its simplest members. The action brought about by them is termed fermentation, and the plants themselves were formerly called ferments. This latter term is now more generally applied to certain highly complex substances contained in the cells of the plants and in the cells of animals and obtainable from them by special means. The modern name "enzyme" is also applied to these bodies.

Experiment 128. Dissolve about 50 g. of commercial glucose in 250 c.c. of water. (If glucose is not available, dissolve the same weight of brown sugar in the same volume of water, add a little sulphuric acid and boil as described in Experiment 123.) Break up about 20 g. of pressed yeast in a little water and add to the sugar solution. Keep the mixture in a large flask in a warm place for two or three days. The temperature should be maintained at 25°–30° C. if possible. The flask should not be corked. It may be fitted with a glass delivery-tube bent twice at right angles (see Fig. 64), the lower end of the tube being dipped into a little lime-water in a beaker. Fermentation soon starts and a gas is produced, as shown by the frothing of the solution and the escape of bubbles through the lime-water. The latter becomes turbid after a time, showing that the gas evolved is carbon dioxide. When no further bubbling occurs, filter the contents of the flask into a second flask and attach the latter to a Liebig condenser. Carefully heat the flask and collect about 60 c.c. of the distillate. Place this in a smaller flask, fitted with a side-tube leading to a condenser. Fit a bored cork to the neck of this flask and fix a thermometer through the cork so that

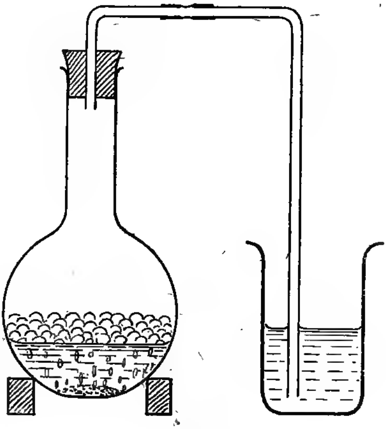

Fig. 64.

the bulb is opposite the opening of the side-tube. (See Fig. 65.) Distil slowly and note the temperature at which distillation commences. Collect the distillate in a small flask and continue the operation until the temperature has risen about 5° above that at which the first drops passed over.

Smell the liquid obtained as the result of the second distillation. It will be found to have a somewhat peculiar odour, in which it may be possible to distinguish a slight resemblance to spirit of wine. Taste a drop of the distillate. The taste is of a somewhat burning character.

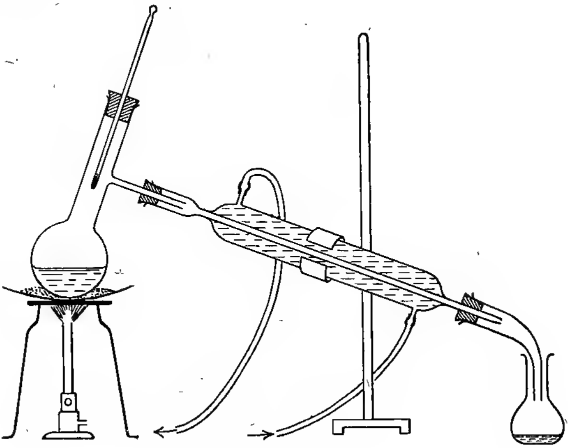

Fig. 65.

Place half the distillate in a small flask, fitted with an upright air-condenser (Experiment 123). Apply gentle heat and, as soon as ebullition starts, put a lighted taper to the top of the glass tube. The vapour will burn with a pale faintly luminous flame.

Pour the remainder into a clean porcelain dish and add two or three small crystals of iodine. Stir until the iodine has dissolved. Add, drop by drop, caustic potash or soda, stirring after each addition, until the yellow colour of the liquid is just discharged. Allow the contents of the dish to stand for some time. A yellow powder slowly forms and settles on the bottom of the dish. Carefully pour away the supernatant liquid and smell the precipitate. The odour of iodoform—a common antiseptic used in surgical cases—will be easily recognised.

The results obtained in testing the distillate show that it contains alcohol. It is, in fact, a weak solution of alcohol in water. The yeast has the power of absorbing the sugar solution and an enzyme, known as *zymase*, contained in the cells brings about the change of the sugar into carbon dioxide and alcohol. The change may be represented thus:

Glucose = ethyl alcohol + carbon dioxide.

We know little about the exact means whereby the zymase is able to effect this change. It has been found that the actual presence of living yeast is not necessary for alcoholic fermentation to occur. The ferment zymase has been separated from the yeast by grinding up the cells with fine sand and water, and filtering the resulting mass under pressure. The filtrate is capable of producing all the phenomena of fermentation. It has even been shown that there are two parts to the filtrate, one being termed zymase proper and the other its co-enzyme. Neither alone can start fermentation, but a mixture of the two reacts at once.

Experiment 129. With a pair of needles mounted in wooden handles tease out a little yeast in a drop of water upon a microscope slide. Examination under a fairly high power of the instrument will show that the plant consists of large numbers of small cells, roughly spherical in shape. Some of these may be seen arranged in chains, which may be single or branched. Fig. 66 is a reproduction of a micro-photograph of a typical sample of yeast.

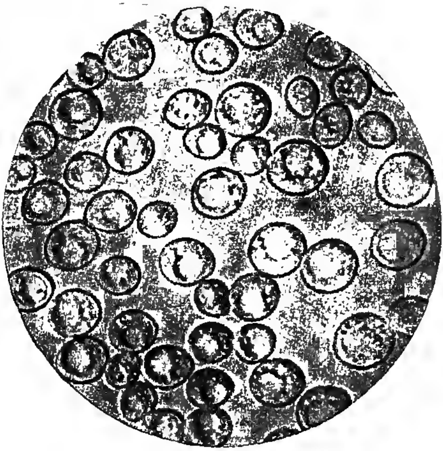

Fig. 66. ×750.

The plant reproduces itself almost entirely by the process termed "budding". A large parent cell develops a swelling at one part, which slowly becomes separated by a layer of the cell-wall, forming a complete separate cell. This may remain in contact with its parent, or may break away and begin life on its own account. The chains of cells sometimes seen are formed by cells remaining in contact long enough for the younger cells themselves to undergo budding. Fig. 67 shows such a chain. The growth and reproduction of yeast depend upon the presence of suitable nitrogenous substances in the media upon which it acts. Such substances are always present in liquids used for brewing and in dough as used for bread-making.

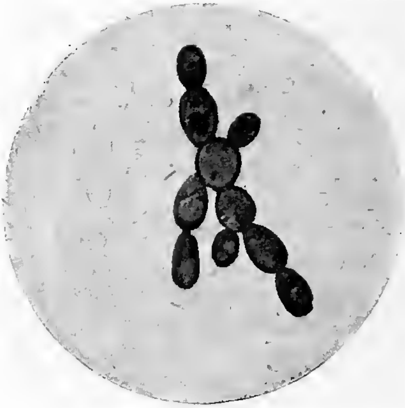

Fig. 67. ×660.

Yeast belongs to the family of fungi known as *Saccharomycetes*, and the common species used in England is *Saccharomyces cerevisiae.*

99. Yeast is an agent of great value in brewing. Beer, ale, stout and porter are fermented drinks produced by the action of yeast upon malted barley steeped in water. Malt contains the enzyme diastase, which, under the influence of warmth and moisture, is able to change the starch of barley into the sugar maltose. Maltose is convertible into glucose by the action of maltase, another enzyme, contained in yeast, and finally glucose is changed into alcohol and carbon

dioxide by zymase, as described above. The nature of the finished product depends upon a number of factors more or less under the control of the maltster and brewer, such as the temperature and duration of malting, the quantity of added hops, starch, sugar, and the like, liquids of different flavour and appearance being thus obtained.

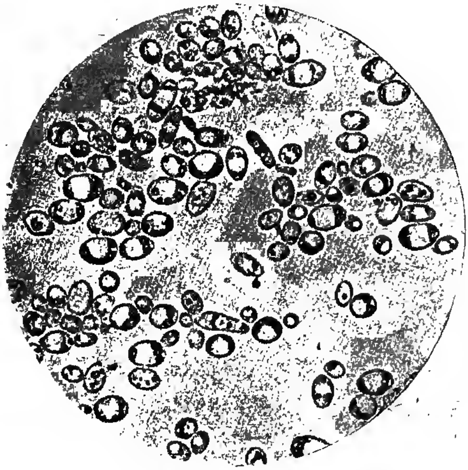

Fig. 68. × 750.

The various wines are prepared from grapes. The addition of yeast is unnecessary, since the skins of the grapes usually provide sufficient cells of the fungus known as *Saccharomyces ellipsoideus* (see Fig. 68), which is capable of causing the fermentation of the grape sugar, expressed from the grapes in the preliminary process of wine-making. No bitter principle similar to that contained in hops is added to wine, and the liquid obtained by pressing—the "must"—is not boiled as is the barley wort in brewing.

The percentage of alcohol in a liquor obtained as the result of fermentation only is comparatively small, ranging from less than 3 per cent in some lager beers to about 14 per cent in the strongest natural wines. Wines containing more alcohol than this have been "fortified" by the addition of raw spirit.

100. Beverages containing a much higher proportion of alcohol are prepared by distillation of fermented liquors. Thus brandy is made from grape-juice (or should be so made), whisky from fermented barley mash or from other grains, rum from fermented molasses, and gin from unmalted grain. The proportion of alcohol in these beverages is very high, the undiluted liquids containing from 45 to 85 per cent. They are in fact strong solutions of alcohol in water. Their varying flavours are derived either from bodies naturally present in the original distillate or produced therein by secondary changes which occur while the spirit is maturing, or by the addition of certain essential oils to the spirit after distillation. Gin, for instance, owes its flavour largely to added oil of juniper.

Ethyl alcohol is prepared in large quantities for use in the arts and in many trade processes. The most common source of such alcohol is the potato. The starch of this vegetable is readily changed into glucose by the action of dilute mineral acids, and the glucose is then fermented and the resulting liquid distilled. By means of distillation in specially constructed apparatus, the proportion of alcohol in the distillate may amount to 95 per cent, the remainder being water. Further removal of water from the "rectified spirit of wine" is effected by adding quicklime, allowing to stand, and again distilling. "Absolute" alcohol is thus produced practically free from water. Commercial absolute alcohol usually contains about 2 per cent of water.

101. When beer or other weak alcoholic solutions are left exposed to the air, they become sour. In this way the first of the acids was obtained, wine being the liquid used. The product is termed vinegar—sour wine—and the acid to which the sourness is due is now known as acetic acid (Latin *acetum*, vinegar). The change effected is of the nature of a fermentation, and the agent in this case is a microscopic plant belonging to the class of fungi, termed *Mycoderma aceti*. The acid is produced by the oxidation, under the influence of the ferment, of the alcohol in the beer or wine by oxygen from the air.

Ethyl alcohol + oxygen
= acetic acid (hydrogen acetate) + hydrogen oxide.

On the large scale vinegar is made by adding wine or fermented malt liquor to some old vinegar and allowing the mixture to remain exposed to the air in casks into which air is able to pass through holes drilled for the purpose. White vinegar is made by what is known as the "quick" vinegar process. Dilute spirit is allowed to trickle slowly through perforated casks filled with beech shavings, the latter having been impregnated with the ferment by use in earlier operations.

The liquid obtained by either of the above means is not pure acetic acid, but a weak solution of the acid in water, the average percentage of acid in brown vinegar being about five. To obtain the pure acid recourse is had to an entirely different method. Wood—such as oak or beech—is distilled in special retorts and the liquid resulting from the destructive distillation of the material is found to consist of two layers, the upper watery layer containing a high proportion of acetic acid. The acid is separated from the accompanying wood-spirit—methyl alcohol—by distillation, the latter boiling at a much lower temperature than the acid. The crude acid is neutralised with lime, and the calcium acetate, after drying, mixed with the calculated quantity of hydrochloric acid. The acetic acid may be obtained in a fairly pure state from this mixture by again distilling.

Experiment 130. The latter part of the process just described may be done in the laboratory. Sodium acetate crystals may replace the calcium acetate with advantage. Thoroughly dry about 20 g. of sodium acetate by heating the crystals in an iron dish—a

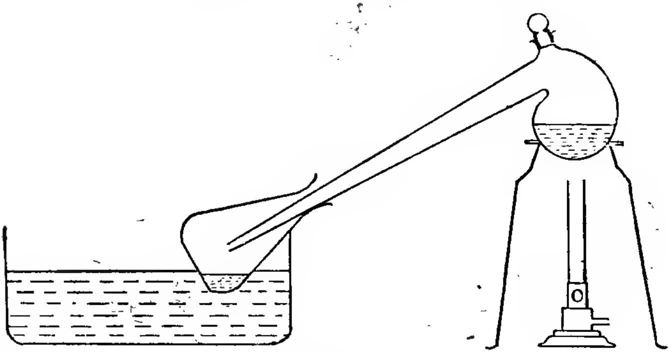

Fig. 69.

sand-bath will do—until no more water vapour is evolved and the resulting mass is fused. Allow the mass to cool and then break up into small lumps. Introduce these into a retort and just cover them with strong sulphuric acid. Heat the retort gently and collect the liquid which passes over in a clean flask. Stop the heating when the drops of distillate become infrequent.

Examine the distillate by each of the following tests:

(*a*) Pour a few drops into about 20 c.c. of water. Taste and smell the weak solution thus obtained.

(*b*) Wet a piece of blue litmus paper with the weak acid.

(*c*) Drop a few crystals of sodium carbonate into a little of the acid. Show that the gas evolved is carbon dioxide.

(*d*) Drop a few small pieces of granulated zinc into a sample of the acid. If necessary, warm the liquid. Show that the gas given off is hydrogen.

(*e*) Colour a little of the acid with litmus solution. Add caustic soda solution, a little at a time, shaking after each addition, until the colour of the litmus is just changed. Evaporate the liquid thus obtained to dryness.

From the results of these tests it will be clear that the distillate corresponds in all particulars to the description of an acid, as given in Part I, Chapter XVIII. It is a strong solution of acetic acid.

### *Exercise for Student.*

Write out the equations for the reactions involved in the preparation of acetic acid and in the tests suggested.

The purest acid is obtained from the distilled acid by cooling it until the greater part of it has crystallised out. The crystals are removed, melted, and recrystallised by cooling. By repetition of this process—known as *fractional crystallisation*—the pure acid may be obtained free from water. It is known as "glacial" acetic acid, from the resemblance of the solid acid to ice.

102. The properties of alcohol and acetic acid may be compared by performing the following tests with specimens of absolute alcohol and glacial acetic acid.

EXPERIMENT 131. (*a*) Shake up some absolute alcohol with water. It readily mixes with the water and no separation of the two liquids is effected on standing. Repeat with varying quantities of alcohol and water. Test the solubility of glacial acetic acid in water in the same way.

(*b*) Put a few drops of alcohol in a porcelain dish and bring the flame of a lighted taper near the surface of the liquid. Its vapour immediately ignites and burns with a characteristic pale blue flame.

Repeat the above test with some glacial acetic acid, warming the contents of the dish with a small Bunsen flame. It will be found that the acid must be heated to near its boiling-point before its vapour will ignite.

(*c*) Test some alcohol with litmus papers and try its solvent powers on sodium carbonate and zinc as was done for acetic acid in the previous experiment.

These tests will serve to show the great difference between the two substances. The acetic acid molecule differs from that of alcohol in that it possesses two atoms of hydrogen less and one atom more of oxygen.

Although composed of the same three elements carbon, hydrogen and oxygen, the properties of the alcohol and acid are quite distinct. The result noted in (*b*) above, where cold acetic acid refuses to ignite while its vapour burns freely when heated, is instructive. It clearly shows that, although the acid contains carbon and hydrogen, the chemical affinities of these elements for oxygen have been partially satisfied by the preliminary oxidation required to transform the easily inflammable alcohol into acetic acid. Further, it is evident that rise of temperature favours chemical action, since the acid burns, *i.e.* its elements carbon and hydrogen combine with oxygen freely, when it is heated.

103. Ethyl alcohol is the most important member of a large series of compounds—the alcohols—of which methyl alcohol and amyl alcohol, the "fusel oil" of whisky and other distilled spirits, are also members. The acids derived from this series of alcohols are the "fatty acids" previously mentioned in Chapter VII. The simplest member of this series is formic acid, while acetic, butyric—the acid developed when butter turns rancid—palmitic and stearic are the best known of the remainder.

The alcohols in general resemble bases and some of the compounds of alcoholic bases with the acids of the fatty series are of importance. Spermaceti is derived from cetyl alcohol and palmitic acid, its chemical name being cetyl palmitate; beeswax is a mixture of myricyl palmitate and ceryl cerotate, and the other animal and vegetable waxes are of somewhat similar composition. We have already seen that many of the fats and oils are salts of the fatty acids with the alcoholic base glycerol.

104. There are some other organic acids which, although they do not belong to the fatty acid series, may well be considered here, on account of the part they play in rendering many fruits palatable and of value as articles of diet.

Oxalic acid occurs in rhubarb, sorrel and other plants, usually in the form of potassium hydrogen oxalate. It may be prepared in the laboratory from cane sugar by treating the latter with strong nitric acid.

EXPERIMENT 132. Place 20 g. of cane sugar in a large porcelain dish and add about 90 c.c. of strong nitric acid. Heat gently until brown fumes begin to be evolved. The heating may then be stopped and the reaction proceeds vigorously for some time. The experiment should be conducted under a hood or in the fume cupboard. On allowing the liquid to cool, crystals of oxalic acid slowly separate out. They may be purified by decanting away the remaining liquid, dissolving the crystals in hot water and recrystallising.

Place a few crystals of the acid in a boiling-tube and pour in a few c.c. of strong sulphuric acid. Heat the tube gently. When effervescence commences, pour a little of the gas produced into another tube and shake up with lime-water. The turbidity obtained shows that carbon dioxide is evolved. Place the flame of a lighted taper at the mouth of the tube in which the action is taking place. The flickering blue flame of the burning gas is evidence that carbon monoxide is also given off.

Dissolve the remainder of the crystals in water and perform tests similar to those mentioned in Experiment 130 with the solution thus obtained. The results will afford evidence that oxalic acid behaves in general in similar fashion to the mineral acids.

Oxalic acid acts as a mild reducing agent, since it is convertible into carbon dioxide and water under the influence of many substances which can supply the necessary oxygen. In the above experiment, the sulphuric acid abstracts the hydrogen and part of the oxygen of the acid, leaving the carbon combined with the remaining oxygen as shown. (Compare its use with potassium permanganate as mentioned in Chapter VII, par. 84.)

A peculiar salt of oxalic acid, consisting of a molecule of the acid potassium salt combined with a molecule of the acid, known as potassium quadroxalate, is sometimes used as an agent for removing iron-mould or ink stains under the name of salts of sorrel. (The name of salts of lemon is also sometimes given to this compound, although lemons contain no oxalic acid.) The quadroxalate combines with the iron to form a soluble iron potassium oxalate which may be washed away.

It must be remembered that oxalic acid and its salts are extremely poisonous and they should always be kept in special bottles, labelled "Poison" in large characters, and should never be left lying about in beakers or dishes. Any unused material should be poured down the sink immediately after use.

105. Grapes contain another acid, tartaric acid. When wine undergoes secondary or "cask" fermentation, potassium acid tartrate is deposited and is known in commerce as "argol". From this substance the tartaric acid required for domestic and other uses is prepared. Purified potassium hydrogen tartrate is known as "cream of tartar", and is used, usually in

conjunction with tartaric acid itself, in the composition of many baking-powders. The object of adding the baking-powder in making bread and cakes is to provide as much carbon dioxide as possible for "raising" purposes, while leaving as little residue in the finished article as may be. Hence the proportions of the various ingredients should be carefully adjusted. The equations representing the reactions of the acid and the cream of tartar upon the bicarbonate of soda which constitutes the third ingredient of the baking-powder are as follows:

$$\left.\begin{array}{c}\text{Hydrogen tartrate}\\ +\\ \text{sodium hydrogen carbonate}\end{array}\right\} = \left\{\begin{array}{l}\text{sodium tartrate}\\ \quad + \\ \text{hydrogen oxide}\\ \quad + \\ \text{carbon dioxide.}\end{array}\right.$$

$$\left.\begin{array}{c}\text{Potassium hydrogen tartrate}\\ +\\ \text{sodium hydrogen carbonate}\end{array}\right\} = \left\{\begin{array}{l}\text{sodium potassium tartrate}\\ \quad + \\ \text{hydrogen oxide + carbon dioxide.}\end{array}\right.$$

The weights of acid and bicarbonate needed to complete the first equation must be in the ratio 25 to 28. For the second equation, the weights of cream of tartar and baking-soda must be as 47 to 21. Thus a baking-powder containing the two former substances should contain them in approximately equal proportions by weight, while a cream of tartar powder requires that about twice as much cream of tartar as baking-soda shall be made use of. The solid acid (or acid salt) and the solid bicarbonate do not react until brought into solution together, and hence it is possible to mix them before use and cause the water required to moisten the flour to act as the solvent. Should they be kept for some time before use, it is advisable to add an equal weight of a starchy material, such as ground rice or arrowroot, to the mixture. This admixture helps to keep the baking-powder dry, the mixed acid and carbonate being somewhat hygroscopic, and further assists in the thorough mixing of the baking-powder with the flour by increasing the bulk of powder required for a given quantity of bread or cake.

The sodium potassium tartrate produced when a baking-powder containing cream of tartar is used is usually termed "Rochelle salt", and is one of the constituents of Fehling's solution.

Tartar emetic is a compound of potassium tartrate with basic antimony tartrate, its strict chemical name being potassium antimonyl tartrate. It is used in medicine as an emetic, whence its name, and also in calico printing as a mordant, *i.e.* colour-fixer.

The familiar Seidlitz powders generally contain tartaric acid in one packet and bicarbonate of soda in the other.

106. Sour gooseberries and lemons owe their taste to the presence of citric acid. This acid is also present in smaller proportion in many other fruits, especially when unripe. It forms the principal ingredient from which is derived the taste of the so-called lemonade crystals and lemonade powders. Its magnesium salt, together with bicarbonate of soda and sugar, gives an effervescing drink when mixed with water, generally termed effervescent citrate of magnesia.

The acid contained in apples, more especially when immature, is malic acid. It is also found in rhubarb and in the berries of the mountain ash.

## QUESTIONS

1. What is yeast? Describe its action upon a solution containing sugar.

2. By what experiments would you show that starch, cane sugar, alcohol and acetic acid contained the elements carbon and hydrogen?

3. What method would you employ to demonstrate that beer contains alcohol? Suggest how a small quantity of fairly pure alcohol may be obtained from a bottle of beer.

4. Why do beer and wine become sour after exposure to the open air? To what substance is the sour taste due?

5. Describe fully any experiment you have performed in which distillation was carried out. What was the object of the distillation in the experiment you describe?

6. Give the chemical names of "salt of sorrel", "spirit of wine", "baking-soda", "washing-soda", "spirit of salt", "water", "Rochelle salt", "soft soap", "olive oil".

7. Show clearly how a specimen of acetic acid may be produced by various changes from potato starch.

8. Why is oxalic acid of use as a cleansing agent? For what special purposes would you recommend its use?

9. Give the composition of any baking-powder with which you are acquainted. For what reason is each of the constituents present?

10. What operations are necessary to separate the constituents of a mixture of cane sugar, starch and chalk? Give clear instructions for obtaining a dry specimen of each substance from such a mixture. Test the method suggested in order to determine its feasibility.

# CHAPTER XI

## FOOD, COOKING, AND DIGESTION

107. The constituents of the numerous substances used by man as food may be roughly grouped into three great classes. These are known as the "foodstuffs" and are (*a*) the carbohydrates, (*b*) the fats, (*c*) the proteins. Of these, we have already dealt at some length with the carbohydrates and, in less detail, the fats have been considered. Both classes contain the elements carbon, hydrogen and oxygen, but the proportion of carbon in the fats is much higher than in the carbohydrates. The different fats and oils vary somewhat in their composition, but the following may be taken as the approximate average percentage composition of fat: carbon, 79; hydrogen, 11; oxygen, 10.

The third class of foodstuffs differs considerably from either of the others. Fats, oils, starches and sugars may be accurately analysed by chemical methods, and, in most cases, we are able to assign definite formulae to their molecules. The molecular formulae of starch and its derivative dextrins are not known with certainty, but the ratios existing between the numbers of carbon, hydrogen and oxygen atoms present in each molecule may be estimated with accuracy. The molecular structure of the proteins is of a more complex character and definite formulae cannot yet be assigned to the various members of this group. The proteins, further, are distinguished by containing more elements, as they all contain nitrogen in addition to carbon, hydrogen and oxygen. Sulphur in small proportion is a constant constituent of protein material and many bodies of this class also contain phosphorus. The percentage composition of the various substances belonging to this class varies within certain limits, the following being rough average values:

Carbon, 50 to 55 per cent; hydrogen, 7 per cent; oxygen, 20 to 24 per cent; nitrogen, 15 per cent; sulphur, 1 per cent.

Protein bodies are found in foods of both animal and vegetable origin. Thus lean meat is largely composed of muscle albumin, which, in the living animal, is known as myosinogen, but becomes changed after death into myosin, another form of protein: blood contains serum albumin and fibrin: white of egg is a nearly pure albumin: milk and cheese contain caseinogen: wheat, gluten: beans and peas, legumin. The proteins are classified according to their behaviour towards various chemical reagents and other properties into several groups, but a description of this system is beyond the scope of this book.

108. The properties which are common to the whole group may be considered, however, as upon these properties depends the value of the proteins as food materials.

All proteins contain nitrogen. It has been shown in Chapter VIII that the detection of the presence of carbon and hydrogen in organic substances is a fairly simple matter. To show the presence of nitrogen, advantage is taken of the observation that when many nitrogenous substances are heated with an alkali, some of the nitrogen and hydrogen contained in them is set free in combination as the gas ammonia.

EXPERIMENT 133. Place about 0·5 g. of lean meat or cheese in the hot air oven at a temperature of about 110° C. until dry. Rub the dried residue up in a mortar with about 3 g. of dry soda lime. Put the mixture into a clean boiling-tube and add about 5 g. of dry soda lime so that it forms a layer above the mixture. Gently heat the tube, beginning at the top of the upper layer and gradually passing the flame to the bottom of the tube. Smell the vapour issuing from the mouth of the tube at intervals and insert a moistened piece of red litmus paper into the vapour. It may be possible to distinguish the peculiar pungent smell of ammonia. The paper will be changed in colour from red to blue. These observations tend to show that a volatile substance has been produced, which has an alkaline reaction when in solution. Ammonia is practically the only substance which answers this description. It is a compound of nitrogen and hydrogen, and its formation in the above experiment is considered as evidence that the material heated with the soda lime contains nitrogen, since the latter does not. (Soda lime is simply lime which has been slaked with caustic soda solution instead of water.)

In order to obtain a supply of ammonia wherewith to examine its properties more readily, we may make use of the strong solution of the gas in water, usually known as 0·880 ammonia from its specific gravity when freshly prepared.

EXPERIMENT 134. Pour about 20 c.c. of this solution into a four-ounce flask, fitted with a cork bored with a single hole for the receipt of a piece of straight tubing about 12 inches long to act as a delivery tube.

*Gently* heat the flask and its contents. Bubbles will soon appear escaping from the liquid. These are bubbles of ammonia. To collect a sample of the gas, fix a clean dry gas-jar over the delivery tube so that the upper end of the tube almost touches the bottom of the gas-jar. (See Fig. 70.) Continue the heating until the ammonia escaping from the mouth of the jar turns a moist turmeric paper dark brown. Raise the jar and slip a glass plate over its mouth. Collect a few more jars in the same fashion.

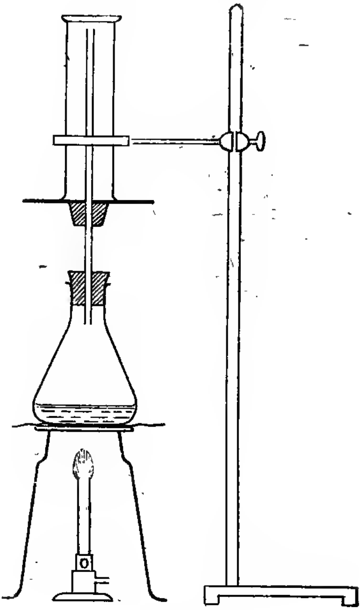

**Fig. 70.**

Experiment 135. Remove the plate from the mouth of one of the jars and place a lighted taper in the jar. The flame of the taper will be extinguished, and the ammonia will not be ignited. Just before the taper is extinguished, however, a flickering yellowish flame may be observed playing around the taper flame proper. The ammonia is burning close to the flame, but is unable to combine directly with the oxygen of the air, except where it is heated to a high temperature in the neighbourhood of the flame. It will burn readily in an atmosphere of oxygen.

Experiment 136. Allow one of the jars to stand with its mouth open and directed upwards for about a minute. Push a lighted taper into the jar. The continued burning of the taper shows that the ammonia has escaped from the jar and hence that it is lighter than air.

Experiment 137. Invert another jar, mouth downwards, in a trough of water, and remove the glass plate under the surface of the water. If the jar was filled with ammonia, the water will rise quickly in the jar and almost fill it. Should it fail to do so, repeat the operation with a fresh jar, which has been held over the delivery-tube for a much longer period. Ammonia is very soluble in water, in this resembling hydrogen chloride.

0·880 ammonia is produced by passing the gas into water until the latter will dissolve no more.

109. To demonstrate that the gas contains nitrogen and hydrogen, it is usual to pass it over hot copper oxide, the oxygen of which combines readily with the hydrogen, leaving the nitrogen in the free state.

Experiment 138. Fit up the apparatus shown in Fig. 71. In the flask place about 20 c.c. of 0·880 ammonia. The drying-tower contains small sticks of caustic potash. The latter may be replaced by small lumps of quicklime, but calcium chloride or sulphuric acid must not be used, since ammonia readily combines with each. The hard glass tube contains copper oxide, preferably in the form of small pieces of oxidised copper wire. This requires to be heated in a small combustion furnace, or by a good Ramsay burner. When the oxide has reached a dull red heat, the flask may be gently heated, so that a steady stream of the gas is caused to pass over the contents of the hard glass tube. Allow the gas to bubble through the water in the trough for a short time in order to ensure the displacement of the air in the apparatus. Then place an inverted jar filled with water over the beehive cell and collect a jar of the gas evolved. Any unchanged ammonia will be absorbed by the water in the trough. Test the gas in the jar with a lighted taper and by shaking up a little lime-water in the jar. The extinction of the flame of the taper, together with the absence of effect upon the lime-water, show that the gas is nitrogen. The presence of hydrogen in the ammonia

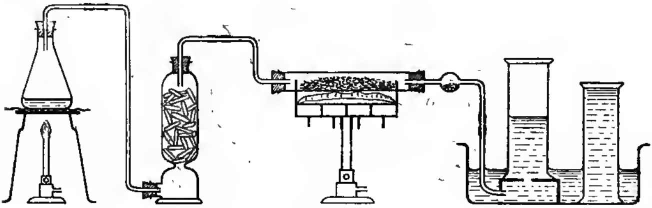

Fig. 71.

may be demonstrated by noting that some of the copper oxide is reduced to metallic copper, and that a few particles of anhydrous copper sulphate placed in the bulb on the delivery-tube are turned blue by the condensation on them of part of the water formed by the union of the hydrogen with the oxygen of the reduced oxide.

Ammonia combines with acids to form salts. With hydrochloric acid it forms ammonium chloride (see Experiment 64); with sulphuric acid, ammonium sulphate. The group ammonium is a good example of a radical. It is present in a large number of compounds, which are found to bear a fairly close general resemblance to the corresponding compounds of the metals potassium and sodium. The solution of ammonia in water, further, behaves like the solutions of sodium hydrate and potassium hydrate in that it is strongly alkaline and may be used to neutralise the most powerful acids. It is frequently called ammonium hydroxide solution, although the compound ammonium hydroxide cannot be isolated in the pure state, as is the case with the hydroxides of potassium and sodium.

110. In addition to evolving ammonia when heated with an alkali, the proteins possess the distinctive property that, when heated alone or in the presence of water, they undergo a peculiar change, termed coagulation. The addition of certain reagents will also bring about this change. The coagulated protein is much less soluble than the native protein.

Experiment 139. Pour a little white of egg into a test-tube. Place the tube in a small beaker partly filled with water. Heat the water gently and note the behaviour of the albumin. Stir the water with the test-tube from time to time. It will be found that the egg-white loses its transparency when the temperature of the water is between 70° and 80° C.

To show the change in solubility, pour about 0·5 c.c. of fresh egg-white into a test-tube half filled with distilled water. Shake the tube well. The albumin will slowly dissolve but the solution will be somewhat turbid, owing to the precipitation of a small quantity of another protein, globulin, which is also present in egg-white. Into another quantity of water put about the same bulk of the coagulated egg-white. It will be found that this will not dissolve, however vigorously the tube be agitated.

Egg albumin is soluble in water, but most other proteins are insoluble in that liquid. Some are soluble in dilute salt solutions, *e.g.* myosin and fibrinogen, while others require the action of weak alkalis before they can be brought into solution. Mucin, a complex protein found in the bile, saliva, and gastric juice, is an example of this last class.

111. Certain reagents produce well-marked colour effects with protein bodies and are generally used to distinguish the latter from other compounds.

EXPERIMENT 140. Prepare a solution of egg albumin in water by carefully breaking an egg and allowing a small quantity of the white to drop into some distilled water. To free the solution from the insoluble egg globulin, the liquid, after thorough shaking, may be strained through two or three layers of fine muslin. Test separate portions of the solution as below:

(*a*) Add a few drops of strong nitric acid. A white precipitate is formed which consists of the albumin, the latter being insoluble in acids. On boiling the liquid, the precipitate turns somewhat yellowish in colour. This colour becomes much darker if the liquid be cooled and a little ammonia solution added. From the nature of the colour produced this test is sometimes termed the *Xanthoproteic* test, *i.e.* the "yellow" test for "proteins".

(*b*) Add a few drops of strong mercuric nitrate solution. (This solution is called Millon's reagent and may be prepared by dissolving 10 g. of mercury in about 7 c.c. of strong nitric acid and adding 15 c.c. of distilled water to the solution thus obtained.) A white precipitate, which becomes brick red on boiling, is characteristic of proteins.

(*c*) Pour a little weak copper sulphate solution into a clean test-tube and then pour away the liquid, leaving a very small quantity adhering to the sides of the tube. Add about 1 c.c. of albumin solution and 2 c.c. of strong solution of caustic potash. The presence of protein is indicated by the production of a violet tint. This test is known as Piotrowski's or the "biuret" test.

112. The proteins are colloidal bodies and hence cannot pass readily through animal membranes.

EXPERIMENT 141. Repeat Experiment 126, substituting white of egg for the starch paste and a piece of stretched bladder for the parchmentised paper. Allow to stand for some hours and test the water after that period for the presence of albumin by the tests given in Experiment 140. No positive reactions should be obtained.

In order to be of service as food, albumins must be rendered diffusible through the animal membranes lining the digestive tract. To this end they are changed by the action of certain constituents in the gastric and pancreatic juices into bodies known as proteoses and peptones. The former are readily diffusible, the latter less so. Commercial peptone, which is usually a mixture of peptone and proteoses, may be shown to diffuse through the membrane as used in the last experiment.

Experiment 142. Shake up a little commercial peptone with a small quantity of water. It will be found to dissolve readily. Place the solution in the dialyser as used in the preceding experiment and allow to stand for some hours. Test the contents of the outer vessel by the biuret test, as described above. Peptone and the proteoses answer to this test, although they are not native proteins, but derivatives of these.

113. Milk—the perfect food of the young mammal—contains all the constituent foodstuffs we have dealt with and its examination for each will afford an interesting exercise.

Experiment 143. Pour about 5 c.c. of milk into a boiling-tube and add an equal bulk of water. Add about five drops of acetic acid and shake well. Allow to stand for a few minutes. The liquid will be separable into two distinct portions—usually known as the "curd" and the "whey". The former consists of the caseinogen of the milk, together with most of the fat. The curdling is evidence of the presence of protein matter precipitable by dilute acid. Filter the liquid through an ordinary filter-paper. The curd remains on the paper, while the whey passes through as an almost colourless liquid.

Treat the curd as follows:

(*a*) Shake some of it, obtained by scraping from the filter-paper with a spatula, with a few c.c. of ether in a test-tube. (Do not perform this operation in the immediate neighbourhood of a naked light, as the ether vapour is very easily inflamed.) Pour a few drops of the ethereal solution upon another filter-paper and allow the ether to evaporate. The presence of a grease spot upon the paper after this treatment will afford evidence of the existence of fat in the milk.

(*b*) Pour away the remaining ether into a bottle kept for the purpose and scrape a portion of the residue into a watch-glass. Put this in a steam or hot-water oven to dry. When dry, test for the presence of nitrogen by heating with soda lime as described in Experiment 133. Put a further quantity into a test-tube and add some Millon's reagent. The production of a brick red colour on warming shows that protein matter is present. The caseinogen of the milk has been precipitated by the acetic acid.

The whey may be treated as follows:

(*a*) To a small portion add a little caustic soda or potash solution, testing with red litmus paper to see that enough has been added to render the liquid faintly alkaline. Add a little Fehling's solution and boil. The formation of a red or reddish-yellow precipitate of cuprous oxide shows that a reducing sugar is present. The sugar in this case is lactose, which is only found in milk.

(*b*) Test another portion with Millon's reagent and warm. A red precipitate will be obtained. This is due to the presence of a second protein in the milk, known as milk-albumin or lactalbumin. This is not coagulated by acetic acid and hence, being also soluble in water, remains in the whey. Its presence in the latter liquid may also be demonstrated by boiling another small portion of the whey in a test-tube. Lactalbumin coagulates on being heated and the liquid is rendered turbid.

(*c*) Evaporate about 3 c.c. of the whey to dryness in a porcelain dish. Strongly heat the residue, which will char, showing that carbon is present, and continue the heating until all the carbon has been burnt. A white residue will remain, consisting of incombustible matter. This is generally called the "ash" of the milk and consists of mineral matter, part of which was contained in solution in the original milk and part produced by the decomposition of other constituents of the milk.

From the above investigation it is clear that milk contains examples of each great class of foodstuffs. The average percentage composition of milk may be considered to be roughly as follows:

| | | | |
|---|---|---|---|
| Water ... ... | 87·3 | Fat ... ... | 3·6 |
| Lactose ... ... | 4·9 | Caseinogen ... | 3·1 |
| Lactalbumin ... | 0·4 | Ash ... ... | 0·7 |

(*Note.* The above is only an approximate "average" composition of cows' milk. The milk of individual cows may contain the main constituents in proportions which differ considerably from the values given.)

114. In Part I, Chapter VI, reference was made to the use of a special form of hydrometer, called the

lactometer, in determining the specific gravity of milk. These instruments are frequently sold marked at different parts of the stem with the marks: M, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$, W. These are understood by the users who are ignorant of the nature of milk to mean that when the lactometer floats with the mark "M" at the level of the sample of milk tested, the sample is necessarily good. When the instrument is immersed so that the mark "$\frac{3}{4}$" is shown at the liquid surface, it is supposed that the milk has been diluted with water to such an extent that the resulting liquid contains one-quarter of its bulk of water, and so on, the reading in water itself being at "W". Such ideas regarding the character of the milk may be quite erroneous, and no definite information concerning the genuineness of a milk supply may be obtained by the use of the lactometer alone.

A better form of instrument is shown in Fig. 72. The numbers are termed the "degrees of gravity" of the milk. In order to convert them into ordinary specific gravities, 1·0 must be written before the reading of the lactometer. Thus, if the reading is 32·5, the specific gravity of the sample of milk is 1·0325.

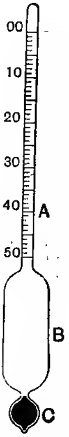

Fig. 72.

Milk consists essentially of a solution of proteins, lactose, and other substances, the specific gravity of this solution being considerably higher than that of water, together with a certain quantity of fat—the cream—distributed in the form of minute globules throughout the solution so as to form a very fine emulsion.

Experiment 144. Dilute a little milk with about five times its volume of water. Place a drop of the diluted milk on a glass slide and cover with a coverslip. Examine the appearance of the liquid under a high power of the microscope. The rounded globules of fat of varying sizes will be readily recognizable. The fat exists in milk in the melted state, so that it may perhaps be considered more correct to speak of oil-globules rather than fat-globules. Fig. 73 gives an idea of the general appearance of cows' milk under the microscope.

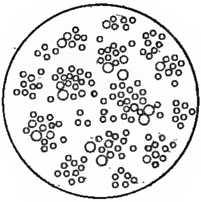

Fig. 73. ×320.

The specific gravity of the fat is considerably less than that of water. The average specific gravity of milk is 1·032. It may readily be seen that the abstraction of the fat, or part of it, from the milk will be followed by an increase in the specific gravity. This may then be reduced to its former value by the addition of water in suitable proportion. The resulting liquid, doubly impoverished by this treatment, will thus indicate, when tested with a lactometer, a specific gravity corresponding to that of good average milk. In order that the determination of the specific gravity may be of real service in estimating the probable genuineness of a sample of milk, its indications must be considered together with the result of a determination of the percentage of fat present. This latter estimation is in general beyond the resources of an ordinary kitchen and the householder is dependent upon the dairy analyst for sufficient information under this head.

115. The greater part of the food consumed by

civilised man has undergone preliminary treatment before he eats it. This treatment usually consists of one or other of the forms of heating grouped under the heading of cookery. We have already seen that heat—especially in the presence of water—has the effect of altering the properties of the various substances of which foods are composed. The examination of the value of the changes brought about in this way from the point of view of the improvement—or otherwise—of the articles treated when used as food will next be briefly dealt with.

Food is rendered more pleasing to the sense of taste, thus stimulating the appetite, and at the same time in many cases is made more readily digestible, by proper cooking. A further advantage arising from the habit of using cooked food is to be found in the sterilizing effect of the temperatures reached during cooking, a point which will receive fuller treatment in a later chapter.

In Chapter IX, par. 97, the matter of the importance of cooking starch was considered. Raw starch is practically indigestible, the outer wall of starch-cellulose being only attacked with great difficulty by the digestive juices, and thus prevents the more digestible granulose within from being acted upon. The action of hot water in causing the rupture of the cell-walls and bringing the starch into the form of a gelatinous solid is the first stage in the change of starch into an assimilable substance. The starch jelly is acted on during digestion by two ferments, the ptyalin of the saliva and the amylopsin of the pancreatic juice. Both have the power of transforming the starch into the simpler body, maltose, this latter body being at a later stage of digestion further changed by the ferment known as invertin, contained in the intestinal juices, into the readily diffusible glucose. It is in the form of glucose that starchy food is absorbed by the digestive organs. Invertin also has the property of acting upon cane sugar or sucrose and transforms it into the simpler sugars dextrose and laevulose, which are both able to permeate animal membranes and are therefore easily absorbed.

116. In temperate regions, civilized man obtains a large proportion of the carbohydrates needed as food in the form of bread. The best bread is made from wheaten flour, a less generally tempting variety being procurable from rye flour. The flour obtained by grinding other cereal grains does not make good bread, since the proteins present do not possess the property of absorbing water to the same extent as gluten. The latter can take up some three times its own weight of water, forming a tough, elastic substance. In all bread-making, except in the case of unleavened bread, carbon dioxide is evolved within the bread-mixture. The bubbles of gas are entangled in the viscous mass produced by the action of the water used upon the gluten in the flour and are thus prevented from escaping. During the baking process the gas expands, and, at a later stage, the gluten hardens. The bread produced is thus obtained as a highly porous foodstuff. The greater the quantity of carbon dioxide retained, the "lighter" the resulting bread. The inability of the proteins of other cereals thus to entangle the gas is the reason for their unsuitability for bread-making.

Bread raised by means of yeast differs slightly in character from bread in which chemical reactions are utilised to produce "lightness". In general, the former is considered the more palatable food. During the growth of the yeast, it acts upon the small proportion of soluble carbohydrates present in the flour, with the result that some alcohol is formed. Most of this is dissipated in the form of vapour during baking, but freshly-made bread still contains a small proportion of alcohol.

As already mentioned, the action of heat and moisture upon starch-grains results in the bursting of the cellulose and the liberation of the contained granulose. The latter substance is readily attacked by the digestive juices. A further change of some of the starch into dextrin in the outer portions of the loaves is effected by the higher temperature of these portions and some small part is even changed to invert sugar by hydrolysis. The crust of well-made bread is somewhat shiny in appearance on account of the dried layer of dextrin present, while its slightly sweet taste is accounted for by the presence of the small quantity of sugar just mentioned.

**117.** The temperatures generally used in cooking operations have little effect upon the chemical nature of fat itself. The fat upon the exterior of a roasting or baking joint may be slightly decomposed and undergo a certain amount of dry or destructive distillation, but that within the joint does not reach a temperature sufficiently high for this decomposition to occur.

The digestion of fats is carried on chiefly in the small intestine. The saliva and gastric juice have no effect upon fats, except that the latter dissolves the walls of the cells surrounding animal fats and thus renders them more easily attacked by the later action of the pancreatic juice. This liquid contains a ferment which is known as steapsin. This is able to split up the fat into glycerine and a fatty acid, the elements of water being added to those contained in the fat. The bile, which is alkaline in reaction and is poured into the alimentary canal at almost the same spot as the pancreatic juice, appears to act in concert with the latter in that the alkaline matter of the bile combines with the fatty acids set free by the pancreatic juice to form soaps. The presence of these soaps assists in the emulsification of any undecomposed fat, and the particles of fat pass through the walls of the intestine and hence into the lymphatic system. From the latter the fat in the form of lymph enters the blood and by its slow oxidation provides heat energy to the body.

118. Of all the fatty substances in general use as foodstuffs, butter is, by common consent, considered to be the most palatable and easy of digestion. It is produced by allowing cream, which contains on an average some 40 per cent of fat, to become slightly soured by bacterial action (see next chapter) and then agitating the product by churning so that the fat is separated from the adherent casein, the fat globules aggregating to form lumps of semi-solid fat. Good butter contains from 80 to 85 per cent by weight of milk-fat, the remainder being chiefly water, with small quantities of milk-sugar and casein. To assist in keeping, salt is added. Ordinary "fresh" butter contains some 2 per cent of added salt, while the proportion in "salt" butters is much higher.

The greater part of butter-fat—some 75 per cent—consists of glyceryl palmitate and oleate in about equal amount. The pleasant flavour and ready digestibility of butter are connected with the presence of compounds of glyceryl with simpler members of the fatty acid series—chiefly myristic, lauric, and butyric acids. The greater volatility of these latter substances imparts the agreeable odour associated with butter.

The comparatively high price of pure butter has led to the manufacture of butter substitutes of which cheaper animal or vegetable fats form the basis. These are known as oleomargarine (or simply "margarine") or butterine. The chief animal fat used is lard, while large quantities of cotton seed oil are also consumed in making some varieties. These materials are purified and then churned in special churns with a certain amount of milk, together with colouring and flavouring materials. A little butter is also added in most cases in order to produce an article more closely resembling the natural product.

The nutritive value of properly made margarine is undoubtedly high and when sold under its proper title little objection can be raised to its use as a food. Its flavour is, however, less delicate than that of butter and hence it possesses less value as an appetizer. Moreover, it is less readily assimilable by persons of weak digestion.

119. The recognition of butter, as distinct from margarine, by its appearance, smell, and taste, is possible to those who regularly handle both articles. Some simple tests whereby information may be gained by others, less skilled, are appended.

EXPERIMENT 145. Place about 10 g. of butter in a small beaker, and in a second similar beaker place about the same weight of margarine. Put the beakers on a sand-bath over a small Bunsen flame. Continue the heating until each liquid reaches its boiling-point. It will be noted that the butter boils almost quietly with much foaming, while the margarine sputters considerably and produces but little foam.

Experiment 146. Add about 20 g. of butter to about 100 c.c. of milk in a small enamelled cup. Heat the cup gently till the butter has entirely melted. Remove the source of heat and stir the mixture vigorously with a lead pencil or other small stick. It will be found that a soft homogeneous mass resembling cream will be produced as a result of this treatment.

Mix similar quantities of margarine and milk and, after melting, beat up as before. The fat will not mix to form a cream, but solidifies in lumps and usually clings to the stirrer so that it may be almost entirely removed.

120. We have seen that many albuminous substances are coagulable by heat at a moderate temperature. In cooking, advantage is taken of this property in the following way. The exterior of a joint of meat is subjected to a high temperature by exposing it close to a bright fire, placing it in a well-heated oven, or plunging it into boiling water. In this way the albumin in the outermost layer of the joint is rapidly coagulated. The formation of a thin skin of coagulated albumin upon the outside of the joint prevents to a large extent the escape of the soluble matters of the meat including the remaining albumin, which is more or less soluble in water. After this preliminary heating at a high temperature, the joint, if roasted or baked, should be either removed from the fire to a

slightly greater distance or placed upon the side of the oven further from the fire. In this way it is kept at a temperature sufficiently high to cause the juices contained in it to approximate to their boiling-point, and the interior is thus cooked in a bath of its own juice. A joint undergoing the process of boiling should, when it has been allowed to remain in boiling water for a few minutes, be thereafter heated more gently, the temperature necessary for the complete cooking of its interior being only about 75° C. Continuous boiling of the water in the cooking vessel only results in the formation of a layer of coagulum of greater thickness, a distinctly undesirable proceeding, since coagulated albumin is exceedingly difficult of digestion.

In various other operations of cookery as usually practised, the object aimed at is essentially the same as that outlined above. Grilling, braising, frying, sautéing and steaming are variants and combinations of the processes already mentioned.

Stewing and soup-making differ from boiling in that the effect of these processes is to extract as much of the soluble and diffusible matter of the food as possible. Hence the use of a high temperature is undesirable throughout and gentle heating at a temperature just below the coagulating point of albumin—say about 72° C.—is most efficacious in ensuring the successful preparation of rich stews and nourishing soups.

Proteid matter is acted upon by both the gastric and pancreatic juices, cp. p. 229, Expt 140. The former contains the enzyme pepsin, which converts the slightly soluble albuminous constituents of food into bodies of somewhat similar composition, called peptones, which differ from albumin in being comparatively much more diffusible. The enzyme trypsin of the pancreatic juice has similar functions, but is able to carry the changes produced further. Bodies known as leucin and tyrosin are thus formed and these may be further decomposed in the large intestine into evil-smelling substances, such as indol and skatol, and even into gases containing sulphur compounds. To the presence of these bodies is due the offensive smell of the undigested portions of the food which leave the body. The juice secreted by the small intestine also contains an enzyme capable of effecting the change of albumin into diffusible substances, or proteolytic fermentation, as it is termed, thus completing the work of proteid digestion begun by the gastric and pancreatic fluids.

## QUESTIONS

1. What method would you adopt in order to determine whether (*a*) rice, (*b*) bread, (*c*) white of egg, contain nitrogen or otherwise?

2. Two jars of a gas are supplied to you. Suggest the tests which you consider the most suitable for finding out whether the gas is ammonia or hydrogen chloride.

3. Milk contains nearly 90 per cent by weight of water. How may a sample of pure water be obtained from it?

4. Into what great classes are the substances used as food usually divided? What differences in composition are associated with this method of division?

5. Is ammonia gas an alkali? Give reasons for your opinion.

6. Suggest objections to the use of uncooked rice as an article of diet.

7. Outline a method by which you consider that the presence of fat and proteid matters in yolk of egg may be demonstrated.

8. How and by what agents is starch changed during the process of digestion?

9. Give the names of three enzymes which take part in the digestive process and state the function of each.

10. What advantages attend the use of cooked food in preference to uncooked? Mention any disadvantages which occur to you.

11. Point out some improper methods of preparing food for the table, mentioning why you think that they are unsatisfactory.

# CHAPTER XII

## PRESERVATION OF FOOD. DISINFECTION

121. In Chapter x mention was made of the fact that a solution of honey or of sugar became changed after exposure to air. It is a matter of common knowledge that other foodstuffs undergo pronounced changes when kept for long periods. These latter changes are generally grouped together under the heading of decay or decomposition. Just as the conversion of a solution of sugar into alcohol and carbon dioxide was shown to be effected by the intervention of a lowly form of plant life—the yeast cell—so may the production of decay be demonstrated to consist in the attack upon the organic matter in the food by various micro-organisms of simple structure. During their growth, these small living plants bring about the decomposition of the complex materials of the food into bodies of much simpler character. The process is allied to fermentation and is usually attended by the absorption of oxygen. Thus the carbon of the

decaying substance is chiefly transformed into carbon dioxide, the hydrogen appears after the change as water, while the nitrogen originally present in the form of very complex albuminous substances is got rid of in the form of ammonia.

EXPERIMENT 147. Obtain a tall gas-jar and fit it with a cork bored to receive two tubes. (See Fig. 74.) Arrange two lengths of glass tubing as shown in the figure. Introduce some decaying matter into the jar. (Some dead leaves in a moist condition will be found to answer well.) Allow the jar to remain for a few days in a warm place, the cork and tubes being in position. At the end of that time, aspirate a gentle current of air through the apparatus and cause the air extracted from the jar to pass through a little lime-water in a second jar (see Part I, Fig. 74) attached to the shorter tube by means of rubber tubing. The almost immediate production of turbidity in the lime-water is an indication that the air in the jar contained a large proportion of carbon dioxide.

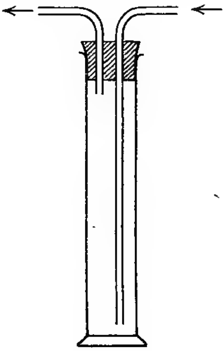

Fig. 74.

122. The plants concerned in the production of these and similar changes are known under the general name of bacteria. They are unicellular organisms which are quite invisible to the naked eye, the largest being about 0·05 mm. in diameter, while forms are known smaller than 0·0005 mm. Bacteria are classified

according to their shapes. Thus those with cells of long rod-like form are called bacilli, rounded cells are termed cocci, and wavy or curved forms are known as spirilli. Vast numbers of bacteria occur in Nature, being found in the air, in soil and in water. Many forms are of the greatest service to animal and vegetable life in general, while others are the cause of diseases in both animals and plants. To the former class belong such forms as the nitrifying bacteria which assist in breaking down nitrogen compounds into simpler substances of value to plants as food, while among the latter are the bacilli of anthrax, consumption, cholera and many other devastating forms of sickness.

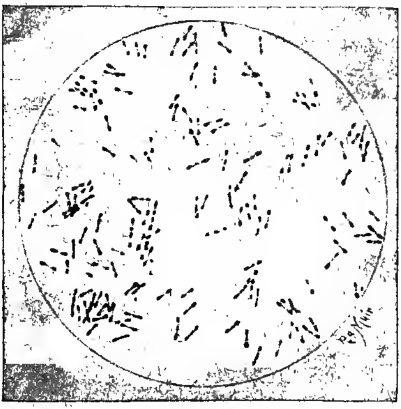

Fig. 75. × 1000.

In Figs. 75, 76, and 77, three varieties of bacteria are shown, all being very highly magnified. Fig. 75 represents a bacillus which causes diphtheria; 76 a coccus, and 77 the cholera vibrio, a spirillum, also known as a "comma" bacillus.

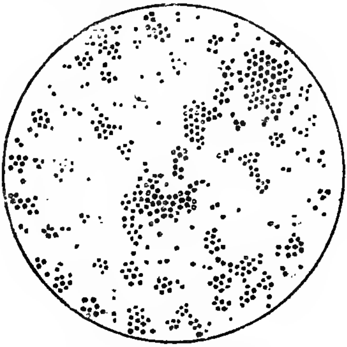

Fig. 76. × 1000.

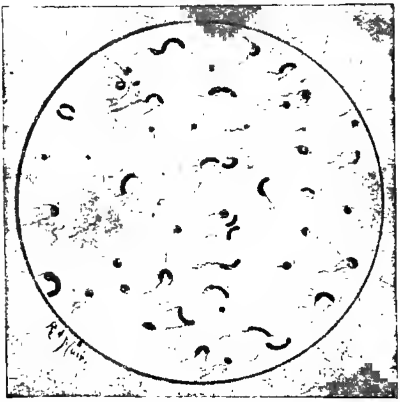

Fig. 77. × 1000.

123. In order that bacteria may flourish, it is essential that they shall find food of the character which suits them, that the temperature shall be between

certain limits, and that moisture shall be present. In the absence of a food supply, bacteria enter upon a resting stage. The cells cease growth but do not die. If, at a later period, they find themselves in more favourable quarters with regard to food, they speedily begin growing and reproducing their kind.

The most favourable temperatures for the growth of bacteria lie in general between 20° and 37° C. Growth and reproduction do not cease entirely when the temperature rises or falls beyond these limits, but become of less vigorous character. At the freezing-point all active increase stops, but the organisms are not killed by frost. Rise of temperature causes decrease of vital activity and at temperatures between 70° and 80° C. the majority of bacteria are killed. Exposure to a temperature rather above that of boiling water for some minutes destroys nearly all the remainder, but the forms most resistant to the action of heat require exposure for some ten minutes to a temperature of about 120° C.

In the absence of moisture, growth does not occur, but the micro-organisms are able to withstand long periods of drought without losing their power of again commencing growth when more favourable conditions ensue.

124. It may be well to attempt some simple experiments in order to bring out more fully the points enumerated above. The necessary materials may be most conveniently procured for a small expenditure from any of the firms dealing in chemical apparatus, since the preparation of most of them in suitable condition requires considerable manipulative skill and more time than can usually be spared by the student.

Nutrient gelatine is made by adding to specially prepared beef broth or "bouillon" about 10 per cent of the finest gelatine. On cooling, the whole mass sets to a firm jelly. This jelly is sterilized—freed from living bacteria—by exposure to a high temperature and is sold in tubes which are stoppered with a wad of cotton wool. This wad must be left in the tube until it is necessary to pour the contents into another vessel.

A Petri dish consists of two small glass dishes of special make which just fit over one another, as shown in Fig. 78. The sterilization of such a dish is effected by placing it in a hot air oven and gradually raising the temperature of the oven to about 170° C. The dish should be allowed to remain in the oven at this temperature for at least one hour.

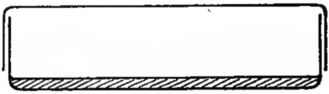

Fig. 78.

Experiment 148. Place a tube of nutrient gelatine in a beaker of water upon a tripod stand and gently heat the water.

When the gelatine has melted, remove the flame and allow the temperature of the water to fall to about 45° C. Place a sterilized and cooled Petri dish in readiness near the tube, remove the latter from the hot water, and pass the end of the cotton wool plug through a Bunsen flame. Blow out the flame of the burning wool; remove the plug and quickly pour the contents of the tube into the Petri dish, holding the cover over the dish while doing so. Allow the dish to stand in a cool place until the gelatine has solidified.

Next remove the upper part of the dish and allow the gelatine to remain exposed to the air of the laboratory for 15 minutes. Replace the cover and keep the dish in a warm place for two or three days. At the end of that time examine the appearance of the gelatine. It will be found to be covered with small whitish spots, among which may sometimes be seen a few coloured masses. Each spot usually represents the progeny of a single bacterium which has fallen on the plate during its exposure to the air. These groups of bacteria are known as colonies. By similarly exposing a number of plates for equal intervals in different localities, an approximate idea may be gained of the comparative freedom from bacteria of the atmosphere in the localities tested.

EXPERIMENT 149. Prepare a second sterilized Petri dish. Remove the cover and pour in a drop of ordinary tap-water, keeping the cover over the lower part of the dish while doing so, in order to prevent as far as possible any contamination by bacteria from the air. Prepare a test-tube of nutrient gelatine at about 45° C. and pour the gelatine into the dish. Rotate the dish—after covering it—so as to mix the water and gelatine as thoroughly as possible. Allow to stand for two days as before and note the appearance of colonies of bacteria as the result of the growth of those originally contained in the tap-water.

EXPERIMENT 150. Prepare some sterile water by boiling some distilled water for an hour in a large flask, the mouth of which has been closed lightly with a plug of cotton wool. (The cotton wool acts as a filter for the bacteria, which are unable to pass through a layer of a centimetre—or even less—in thickness.) Sterilize two 100 c.c. flasks, provided with glass stoppers, in the hot air oven as described for the Petri dishes. Four pipettes of a capacity of 1 c.c., each with a small cotton wool plug near its upper end, should also be sterilized in the same way. (Satisfactory pipettes may be made by drawing out a piece of ordinary glass tubing, breaking off the drawn-out portion, and rounding off the jets in the Bunsen flame. The graduation of such a pipette may be effected by closing the jet with a small piece of paraffin wax and weighing the pipette. Water may then be allowed to run in at the open end from a piece of capillary tubing until the weight has increased by one gram. A scratch may then be made on the tube with a triangular file at the level of the bottom of the meniscus.) Test the sterility of the sample of water obtained as above by running 1 c.c. by means of a sterile pipette into a sterile Petri dish, adding the contents of a tube of nutrient gelatine, and allowing the dish to stand for some days.

With a sterile pipette, run 1 c.c. of milk into one of the 100 c.c. flasks. Fill the flask to the mark with sterile water, replace the stopper and shake well. Using the second sterile pipette, transfer 1 c.c. of the diluted milk to the second 100 c.c. flask and fill up with sterile water as before. Shake thoroughly. This flask now contains milk which has been diluted 10,000 times, *i.e.* each c.c. of the contents of the flask contains 0·0001 c.c. of milk.

Use the fourth sterile pipette to transfer 1 c.c. of the highly diluted milk to a Petri dish, add the contents of a tube of nutrient gelatine, and allow to stand for two days. A large number of colonies will probably be found upon the gelatine at the expiration of this period. If they are not too numerous, try to count them. The result of the counting, multiplied by 10,000, will give an approximate idea of the number of bacteria contained in 1 c.c. of the original milk.

The number thus obtained will in all probability strike the observer as being very large. Most of the forms present are, however, quite harmless to the human organism. The number found in 1 c.c. of a good sample of milk may be less than 10,000, while in samples which have been subjected to contamination or kept for some time at a fairly high temperature, the number per c.c. may be as high as 2,000,000.

125. In order to discover the actual nature of the bacteria present in any given sample of food, further examination is necessary. By means of a sterilized platinum needle, a minute portion of a colony is removed from a plate and a tube containing a nutrient medium is "inoculated" by smearing the surface of the medium with the needle. Several tubes containing different media may be prepared in this way. From the observations of the behaviour of the bacterium towards the various media, it may be roughly classified. A sample is also examined, after staining with a suitable stain, under a very high power of the microscope. After careful investigation in this manner, the actual character of the bacterium may usually be determined. Such work is only of value when performed by skilled observers, and further description is beyond our scope.

126. In examining the appearance of the nutrient

gelatine after cultivation as outlined in the preceding experiments, the observer will probably have noted some patches of comparatively large size and of a somewhat woolly appearance. These may be white, pale green, blue, reddish, or otherwise coloured. Such growths are not due to bacteria, but to the propagation of higher members of the class of fungi. These are generally grouped together under the term "moulds". The rapid appearance of patches of mould on foodstuffs left exposed to the air for a few days is a matter of common observation. They are caused by the settling of minute cells, termed "spores", which are carried by air-currents from other specimens of these lowly plants into all parts of the atmosphere. The purest country or seaside air is not free from such spores, which are so extremely light that they only settle very slowly even in still air. Like bacteria, these fungi are either parasitic, *i.e.* able to live only upon other living matter, or saprophytic, *i.e.* their food consists of dead organic substance. The moulds belong to the class of saprophytes, while somewhat similar parasitic forms cause many troublesome diseases in some of our most valuable food-plants.

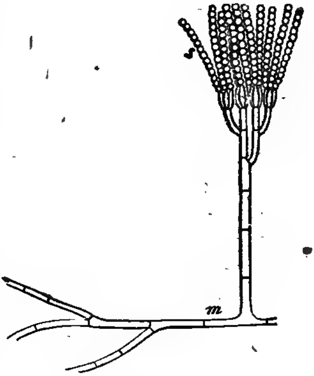

Fig. 79.

The common pale green or bluish mould which soon appears on jam, bread, cheese and other foods may be taken as a typical example. Its systematic name is

*Penicillium glaucum.* Examination under the microscope reveals it as composed of a network of fine threads or *hyphae*, known as the *mycelium* (*m* in Fig. 79). From certain parts of the mycelium erect stalks arise, termed *aerial hyphae.* These bear upon their upper ends branches ending in clusters of small spherical cells. These are the spores, which may be compared to the seeds of higher plants. They are marked by an *s* in the diagram and, in the case of Penicillium, are strictly termed *gonidia.* The bluish colour of the mould is due to these gonidia. The mature gonidia readily break away from the parent plant and are carried by the air to other quarters. Should suitable foodstuffs be there present, each gonidium begins to grow and rapidly develops into a replica of its parent.

The presence of moulds is an indication of decay, and in general, foods which have become mouldy should not be eaten. In some cases, however, the growth of the mould develops flavouring matters in the food which render it agreeable to some palates. Thus some forms of cheese are not usually eaten until mouldiness has set in.

127. Those forms of bacteria which produce disease are grouped under the heading of "pathogenic" organisms. Their presence in food is, of course, greatly to be deprecated. The ideal food would be entirely free from such bacteria, but in practice it is extremely difficult to prevent completely their entry into food. In order to guard against trouble arising from their presence, many methods have been devised for the sterilization of foods. In such sterilization, however, it must be remembered that *all* bacteria, both helpful and harmful, are destroyed, and the

nature of the foodstuffs is usually changed to some extent.

From what has been already said, it will be inferred that subjection to the temperature of boiling water, followed by the prevention by suitable means of further infection, is the best method of preservation of food. It is largely made use of in keeping many forms of food, *e.g.* jams, tinned meats and vegetables, and bottled fruits. In jam-making, the large amount of sugar added acts to some extent as a preservative, and it further assists by causing the temperature of the boiling jam to be higher than that of boiling water, thus effecting the destruction of any germs present in the fruit with greater certainty. In the operation of tinning food, the meat is placed in the tin after a preliminary cooking, and the lid is soldered down, a small hole being left unsoldered. The tin and its contents are placed in a boiling solution of the chloride of zinc or of calcium, and allowed to remain till steam no longer escapes freely from the hole. The temperature of the zinc chloride solution is considerably above 100° C., thus ensuring the complete displacement of any air contained in the tin by steam. While still hot, the hole is soldered up. The contents of such a tin, properly prepared, will remain good for years. Should the heating have been insufficient, the bacteria remaining alive will soon begin growing and reproducing their kind. Their vital activities will be attended by the production of gases, which will exert increased pressure upon the interior of the tin, causing it to bulge. On opening such a tin, there will be an outrush of the imprisoned gas, while a tin in good condition, on being opened, will show the opposite effect.

*Exercise for Student.*

Why does air enter a tin when the latter is opened, provided that it has been filled under proper conditions?

128. Since the growth of bacteria is checked by a low temperature, it is possible to prevent the decay of foods taking place with its usual rapidity by keeping the food sufficiently cool. Milk is thus kept sweet during hot summer weather. If allowed to attain the temperature of its surroundings, bacterial growth is rapid, with the consequent formation of lactic acid in considerable quantities from the lactose present, and the milk soon becomes sour. If cooled to a temperature of 50° F. (= 10° C.), or less, as soon as practicable after being drawn from the cow, and kept cool until consumed, the milk is available for a much longer time as a palatable and wholesome article of diet.

Large quantities of meat are preserved in similar fashion, and much of the meat sold in this country has been brought from America, Australia, or New Zealand in ships fitted with special refrigerating chambers, in which the carcases are kept at a temperature at or just above the freezing-point for long periods. Such meat is quite wholesome, but it must be remembered that the bacteria are not killed by refrigeration, and rapid growth is usually set up as soon as the meat leaves the cooling apparatus. Hence it should be cooked immediately, if decay and its consequent dangers are to be avoided.

Another method sometimes practised for preserving meat depends upon the inhibition of bacterial growth by the absence of moisture. Thorough drying of the meat, either by artificial heat or by that of the sun in hot countries, will tend to keep meat sweet for much longer periods than is the case with untreated flesh.

129. Many chemical substances serve to retard the increase of bacteria while being more or less harmless to animal life. Under this head come such processes as salting of meat by immersion in brine or solutions of other salts, such as nitre (potassium nitrate), treatment of meat by injecting preservative fluids, *e.g.* brine or solution of alum, and also the application of preservative substances, such as borax and boric acid, salt, sugar, and salicylic acid, to the articles requiring preservation. Foods treated in either of these ways are not as suitable for human consumption as the same foods in a fresh state. Preservation should only be resorted to when circumstances render it necessary and never as a means of disguising the staleness and incipient decay of any article of diet.

It should further be noted that the preservative effect of the above methods of treatment is not permanent, and the consumption of such foods may give rise to serious ailments if they are not used while comparatively recently treated. The added substances do not entirely prohibit bacterial life but greatly retard it and the effect becomes less with lapse of time.

Many of the preservatives which may be used are in themselves dangerous to life. In large doses such a substance as salicylic acid is poisonous, and even borax and boric acid are said to bring about digestive disturbances in certain cases. The use of so powerful a poison as copper sulphate solution to cause preserved peas to retain a bright green colour cannot be too strongly condemned.

The influence of preservatives upon bacterial growth may readily be illustrated by a simple experiment.

Experiment 151. Procure a pint of fresh milk, place it in a clean stoppered bottle and shake the bottle so that the various constituents of the milk may be well mixed. In each of four separate clean glass bottles, provided with glass stoppers, measure out 100 c.c. of the well-mixed milk. Close one bottle and put it on one side. Weigh out 10 g. of borax, place it in a 100 c.c. graduated flask, add water to the mark, and shake till all the salt has dissolved. 1 c.c. of this solution will contain 0·1 g. of borax. To the milk in a second bottle add 1 c.c. of the solution by means of a pipette (see previous experiment) and replace the stopper. Shake the bottle gently to distribute the preservative solution throughout the liquid. Add 5 c.c. of borax solution to the milk in the third bottle, and 10 c.c. to the contents of the fourth. Shake gently, label each bottle suitably, and put all the bottles in a safe place. Examine the contents of each bottle at the end of 24 hours. Note especially whether the smell of the milk has become unpleasant and whether there is any sign of curdling. Record the results of your examination. Similarly inspect the bottles daily until each contains two distinct layers of fluid.

It will be found that the untreated milk first shows signs of decomposition, and that those containing preservative become sour in order, commencing with that to which the least quantity of borax was added.

If time permit, a rough comparison of the number of bacteria present in each sample at the end of a given time—say three days—may be made by shaking the contents of each bottle and then treating 1 c.c. of its contents as described for fresh milk in Experiment 150. In the case of the untreated milk it may be advisable to dilute three times instead of twice, in order that the number of colonies may not be too large to estimate with fair accuracy.

The souring of milk is due to the action of several bacteria, of which the lactic acid bacillus is the most important. These organisms are able to act upon the lactose in the milk in such a manner that it is changed into an acid, known as lactic acid. We have already seen that the casein of milk is coagulable by acids (see Experiment 143). When the proportion of lactic acid produced is sufficiently high, a curd is formed. This is evidence that bacterial growth has taken place to a considerable extent. The longer time taken for the formation of curd in the case of the preserved milks illustrates the retarding influence exercised upon the vital activities of bacteria by the presence of a chemical preservative. The proportions of borax added in the two latter cases are greater than usually practised by either fraudulent dairymen or unwisely economical householders, since it is rarely the case that it is desired to keep milk sweet for longer periods than one or two days beyond the normal time.

130. Closely allied with the subject of food preservation is the question of the prevention of the spread of communicable diseases. Nearly all these have been shown to be directly concerned with the presence of specific bacteria in the tissues of the person affected. These also may be found in healthy persons, but their existence in such cases is usually brief, since the conditions are not favourable to their growth and

reproduction. Should they find their way into the tissues of a person predisposed by certain weakening influences so as to be unable to withstand their attack, their increase sets up the disease with which they are specially connected.

The discussion of the various methods by which the bacteria are disseminated is beyond the scope of this book, but it may be briefly stated that some are carried by the air, others enter the body in water used for drinking, others are transmitted by way of clothing, books, furniture and similar articles which have been used by or otherwise come into contact with a previous sufferer from disease, while flies, mosquitoes and even larger animals have been shown to play very important parts as carriers of disease germs.

131. One of the most important factors in the prevention of the spread of communicable diseases is provided by the methods of disinfection in general use in civilised countries. It will be well to explain the meaning of some terms used in this connection before proceeding further. A *disinfectant* is a substance which is capable of destroying the bacteria or germs which cause disease. The name *germicide* is sometimes given to such bodies and it should be remembered that a true disinfectant is always a germicide. An *antiseptic* is a substance which is able to stop, either partially or entirely, the growth of germs. The latter are not necessarily killed and may later find themselves under favourable conditions for growth and in consequence may possibly cause a further outbreak of disease. A *deodorant*, as its name implies, is merely a substance which is capable of masking the unpleasant smells which frequently accompany the progress of certain

diseases. It may not have the slightest effect upon the bacteria and is quite useless as a preventative of further infection. The word *aseptic* is also of frequent occurrence in dealing with surgical treatment. It refers to the method, first introduced by Lord Lister, of carrying out all surgical operations, however slight, in such a manner that the entrance of bacteria into the affected part is impossible, since all appliances and materials used are so treated beforehand that bacterial life is absent. The severe inflammation which was the general accompaniment of almost all operations in earlier surgery, and was the cause of much unnecessary suffering and loss of life, is now almost unknown.

In the succeeding paragraphs the use and value of various substances for the purpose of disinfection will be dealt with. It must be clearly understood that protection against disease is only afforded by the use of suitable disinfectants of proper strength and that the idea, still prevalent to a considerable extent, that antiseptics and deodorants are of avail in this connection is quite misleading and may be the cause of serious trouble.

132. First on our list of disinfectants come the cheapest of all, sunlight and fresh air. Though of least cost, they are nevertheless of the highest efficiency. Many disease germs are unable to exist in bright light and others are killed by oxygen. The former statement may be proved by a simple experiment. A culture tube containing pathogenic organisms is covered with several layers of black paper in which a small hole has been cut. After allowing the germs to remain under suitable conditions for growth for some days, the part of the tube beneath the hole being exposed to sunlight, it is found that growth has taken place

freely in the darkened portions of the medium, while it has been stopped in that which has been exposed to the light. That many disease germs will not grow in the presence of air or oxygen is shown by the fact that, in order to obtain cultures of them upon the usual nutrient media, the air, or at least the oxygen, within the culture tubes has to be removed in order for growth to take place. Evidently the free entrance of light and air into dwelling-houses is of the greatest service in combating disease. The greater prevalence of infectious diseases among the poorer members of the community, who are housed under conditions which sometimes prevent the due proportion of light and air from entering their dwellings, and who are, moreover, often ignorant of the beneficent effects of open doors and windows, tends to show that this argument is sound.

We have already learnt that bacteria are destroyed by exposure to a high temperature. This observation finds application in many ways. All articles of little value which have been contaminated during the progress of an illness of an infectious nature should be burnt. In this way the destruction of any adherent bacteria is rendered absolutely certain. It would perhaps be well if this treatment could be applied to all articles which have been exposed to infection in the case of the more serious communicable ailments, but such a counsel of perfection can scarcely be carried out at the present day. Everything which has come into close personal contact with the victim of the disease, such as articles of clothing and bedding, and all other articles which will not be harmed by the treatment, *e.g.* curtains and window-blinds, should be subjected to the action of saturated steam for a length of time sufficient to raise the temperature of the innermost parts of the articles to a temperature equal to that of the boiling-point of water. Five to ten minutes exposure to steam at 100° C. is usually sufficient to kill even the highly resistant spores of certain bacteria. Articles so treated should afterwards be dried thoroughly by the action of a current of air at a high temperature.

Hot air, if dry, has been found to be much less efficacious than steam as a germicide. When its use is rendered necessary as a substitute for steam, as in the case of books and other articles which would be destroyed by exposure to steam, its application must be prolonged. Roughly speaking, the number of hours exposure to hot air should be about the same as the number of minutes required for steam disinfection.

The expression *saturated steam* used above may require some explanation. When steam is generated in the open air, its temperature is practically the same as that of the boiling water from which it is escaping. A very slight lowering of temperature is sufficient to condense such steam completely. When water is boiled under pressure, the temperature at which ebullition occurs is raised and the temperature of the escaping steam is raised to the same extent. Steam produced under such conditions will still condense if the temperature be lowered however slightly. Both kinds of steam just described are termed saturated. The temperature of steam may be raised in a different way from that just described. By boiling water under atmospheric pressure and then passing the issuing steam through a glass or metal tube heated to a temperature above 100° C., the steam may be made hotter to any desired extent. Such steam is termed *dry* or *superheated* steam, and will not condense to water as the result of a slight lowering of temperature. The temperature must fall to that at which the steam was generated before condensation occurs.

The above statements may be roughly illustrated by a very simple experiment.

EXPERIMENT 152. Fit up the apparatus shown in the annexed figure. The water in the flask may be made to boil gently and the escaping steam at the end of the copper tube lying above the Ramsay burner will be found to condense almost as soon as it leaves the tube, as shown by the formation of the familiar cloud of minute drops of water quite close to the end of the tube. Now light the burner beneath the copper tube and note the change in the distance which separates the cloud of condensed steam from the end of the tube as the latter rises in temperature. It will be seen that

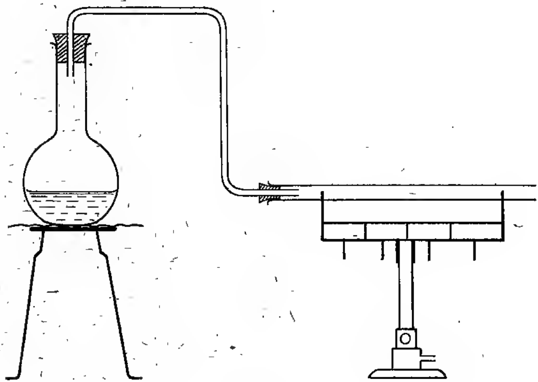

Fig. 80.

this distance increases considerably with rise of temperature and at length becomes of practically constant length. Evidently the dry steam now escaping from the tube takes a longer time to cool to its condensing point than does the saturated steam which was first passed through the tube.

On the large scale, as in municipal disinfecting stations, saturated steam under pressure is commonly used for disinfecting bedding, blankets, and similar articles. The advantage of saturated over superheated steam lies in the readiness with which the former condenses, giving up simultaneously its latent heat of vaporisation and thus raising the temperature of the bodies in contact with it much more rapidly than is the case with dry steam. The condensation of a large volume of steam, further, results in the formation of a very small quantity of water. This causes a considerable reduction of pressure within the disinfecting apparatus and makes the succeeding quantities of steam rush more rapidly into the interior of the articles and consequently raises their temperature at a greater rate.

133. The disinfection of rooms in which patients suffering from communicable diseases have been treated is usually performed by fumigation. All paper should be stripped from the walls and burnt. All cupboards and drawers should be opened to their fullest extent and all furniture removed from contact with the walls. The chimney and window sashes should be stopped up as completely as possible, as should the cracks around the door after the disinfection has been started. The gases in general use for fumigation are sulphur dioxide and formaldehyde. The former is obtained by burning

sulphur in a vessel placed over a larger vessel containing water, in the middle of the room. About one pound of sulphur may conveniently be burnt in this way and the weight of sulphur required for satisfactory disinfection of the room will depend upon the size. It is usual to burn about 3 lb. of sulphur for each 1000 cubic feet. Each pound of sulphur used is best placed in a separate vessel and the various vessels distributed about the floor of the room. After the room has been sealed for at least 24 hours, the door and windows should be opened fully and the room thoroughly flushed with fresh air for several hours.

Formaldehyde may be obtained in a condensed form as paraformaldehyde. This is a solid and requires vaporisation by heating with a spirit or other convenient lamp. In practice, the best results are obtained when the substance is vaporised in a special form of apparatus. The room should be carefully closed and the vapour allowed to act for some hours. Preliminary spraying of the walls and floor of the room with a dilute solution of formalin is of service in effecting complete disinfection. Formalin is the trade name for a 40 per cent solution of formaldehyde.

Gaseous or "aerial" disinfection, as the above process is sometimes termed, is not entirely satisfactory and should be followed by a thorough washing of the floor, walls and ceiling with a strong solution of a good disinfectant. For this purpose, mercuric chloride (corrosive sublimate) is perhaps the best substance to use. A solution of this salt containing one part of salt in 1000 parts of water is strong enough to kill bacteria. The great objection to its use is that it is an extremely virulent poison. The danger of its being accidentally taken internally may, however, be largely got rid of by mixing a quantity of a strongly coloured liquid with the corrosive sublimate solution. Copper sulphate answers very well. A stock solution may be prepared for use containing 1 oz. of the chloride dissolved in a quart of hot water to which about the same weight of copper sulphate has been added. For use, this solution may be diluted 25 times, say, one quarter of a pint to a small bucketful of water. Since the chloride readily attacks metals if kept in contact with them for any length of time, the stock solution should be stored in a clear glass bottle, labelled "poison". Where a municipal station is not convenient, clothes and bedding may be steeped in the diluted solution for 24 hours and then washed and dried in the usual way. Floors, walls and ceilings may be washed with the solution, as also may all woodwork.

134. Many of the modern substances sold as disinfectants are derived from the by-products of gas and coke works. Some of these bodies are quite satisfactory as germicides and are somewhat safer to use than is the chloride of mercury. Izal, cyllin, lysol, and carbolic acid (phenol) may be mentioned as among the best. They may be used for disinfecting clothes and bedding and as washes for floors, walls and furniture. Phenol and izal should be of about five per cent strength, *i.e.* diluted with about 20 parts of water, while cyllin and lysol may be made up of lesser strength, one to two per cent.

All strong acids and alkalis and many solutions of salts are fatal to bacterial life, but their use is extremely limited since they are powerfully corrosive in action and readily destroy fabrics, wood, and other substances of organic origin, as well as many metals, when allowed to remain in contact with articles made of the above for a length of time sufficient to ensure disinfection. The use of chlorine as a disinfectant is attended with similar disadvantages, while its powerful action upon the human economy renders it a most dangerous disinfecting agent except in skilled hands. Hydrochloric acid is a powerful disinfectant and may be used for cleaning the traps of water-closets, where these are free from metallic parts. A mixture of the strong commercial acid with twice its bulk of water, if allowed to stand in the trap for a few minutes, will effectually destroy all bacteria and remove all unpleasant deposit. Condy's fluid—a solution of the manganate and permanganate of sodium—is also of service in this connection. It should be used in such quantity that a distinct pink coloration remains at the end of ten minutes after it has been poured into the trap.

Numerous other substances are sold as disinfectants and are of varying value in this respect. Those which are in the form of powders are of little use as true disinfectants but are very serviceable as deodorants and have, in many cases, considerable antiseptic properties. Where any doubt is felt as to the relative value of any of the commercial preparations, it is best to follow the advice of a physician or a responsible chemist. The indiscriminate use of a well-advertised preparation may produce a false sense of security while the actual degree of safety attained may be vanishingly small.

135. The method of sterilization of water containing harmful bacteria is of great importance. From what has already been mentioned, it is clear that the

simplest method is to boil the water, or, if a very high degree of purity is required, the process of distillation is employed. For small quantities of water, these methods are admirable, but the cost of the necessary fuel renders them less suitable for the treatment of water in bulk.

Efficient filtration will remove bacteria if proper attention be given to the cleansing and sterilization of the filtering medium. (See Chapter v.)

Where the application of any of the above methods presents difficulty, recourse may be had to the use of chemicals as sterilizing agents. Of these, chloride of lime is simple in use and costs less than others sometimes employed. The method recommended for its use in sterilizing water for the use of the army is as follows:

"Take a teaspoonful of good bleaching-powder—containing at least one-third of its weight of available chlorine—and remove the excess of powder by rolling a pencil along the top of the spoon. Dissolve the powder in a cupful of water, making sure that all lumps are thoroughly broken up, and then add three more cupfuls of water to the solution. Stir up the mixture and allow it to stand for a few seconds to let any particles settle. (This stock solution, if kept tightly stoppered, may be used for four or five days.) Add *one teaspoonful* of this milky solution to two gallons of the water to be purified. Stir thoroughly and allow to stand for ten minutes. This will give one-half part of chlorine to 1,000,000 parts of water; 1 lb. of bleaching-powder is sufficient for 66,000 gallons".

It should be noted that the bleaching-powder must be kept in vessels with closely fitting lids or stoppers, since the carbonic acid, formed from carbon dioxide and aqueous vapour, present in the air is able to set free chlorine from the powder. (See Chapter x.)

Another method which has met with some success is that of ozonizing water. Ozone is a peculiar modification of oxygen which possesses more vigorous oxidizing powers than the free element itself and is able to kill bacteria by reason of this property.

## QUESTIONS

1. Distinguish between a disinfectant and an antiseptic. Give some examples of each, with reasons for your classification.

2. What steps would you consider necessary for the proper disinfection of a schoolroom after an outbreak of scarlet fever?

3. Describe some simple experiments whereby the presence of micro-organisms in a sample of well-water may be demonstrated.

4. Why does properly "tinned" cooked meat keep wholesome for a much longer period than cooked meat allowed to remain in the open air?

5. Explain clearly what is meant by each of the following: (*a*) germicide; (*b*) saturated steam; (*c*) superheated steam. Which of the latter two is the better germicide? Why?

6. What conditions are requisite for the propagation of bacteria? Describe experiments in support of your statement.

7. Discuss the suitability or otherwise of the addition of chemical preservatives to articles of food.

8. What do you consider the best means of disinfecting bedding (*a*) at home; (*b*) at a public health station?

9. To what do you ascribe the disinfecting properties of (*a*) sunlight; (*b*) formaldehyde; (*c*) sulphur dioxide; (*d*) mercuric chloride?

10. Eau-de-Cologne is sometimes sprinkled around a sick-room. Why is this done? Discuss the possible danger arising from this practice.

11. Describe a method of obtaining drinkable water from a source known to be contaminated with the products of organic decay.

# CHAPTER XIII

## METALS IN DOMESTIC USE

136. In previous chapters many simple experiments have been described in illustration of the various matters dealt with. In general the observations to be expected have been indicated and the student has not been required to determine independently the inferences that may safely be drawn from such observations. We have in this way made use of the results of the work of previous investigators and much time and trouble has thereby been saved. It must be remembered, however, that the earlier work upon each portion of our subject already considered was done by those who were unable to take advantage of previous experience in this way and hence were obliged to discover for themselves the true interpretation of the results of their work.

In other words, the first experiments were all of the nature of research. In some cases the experiments were undertaken almost by chance; in others, a definite object was before the minds of the workers from the start. Among the former class of experiments may be mentioned the discovery of oxygen by Priestley, who was led to make experiments upon the action of heat on various bodies through being presented with a particularly fine specimen of a "burning-glass". On heating with the aid of this lens some mercuric oxide contained in a capsule floating on mercury in a cylinder inverted over that liquid, he obtained a gas of which he writes: "But what surprised me more than I can well express was that a candle burned in this air with a remarkable brilliant flame". An example of research undertaken with a definite object in view is afforded by the labours of Rayleigh and Ramsay, the discoverers of argon. It had been noted that atmospheric nitrogen was always somewhat denser than nitrogen prepared by chemical methods and it was inferred that the difference was probably due to the presence in atmospheric "nitrogen" of a gas of greater density than that of nitrogen itself. A series of carefully designed experiments was carried out and resulted in the isolation of argon. Modern research is usually of this latter character.

137. The manipulative power and habit of close observation which should have been acquired by the student as the result of the work already done may now be rendered of service in carrying out some research work of an elementary character. It is intended that the present chapter shall consist of what may be considered as an outline of a possible method of conducting a simple inquiry into the suitability for their purpose of the various metals used in the construction of domestic utensils and household fittings. The experiments suggested to be performed are not supposed to exhaust the range of what may be

attempted; rather is it hoped that they may be found suggestive, and that the inquirer may be stimulated by their performance to attempt others independently, in order to elucidate completely any doubtful point, or to emphasize some special feature which may have aroused interest. The results obtained may further be examined with a view to the formulation of the necessary precautions to be observed in the choice and treatment of metal utensils and fittings.

138. Among the metals utilized in the construction of household gear, the most important are iron, tin, copper, aluminium, lead, zinc, and silver. Iron is to be found in three forms of cast iron, wrought iron, and steel. The other metals may be used alone, but mixtures of metals, known as "alloys", are also employed for special purposes. Solder, consisting roughly of equal parts by weight of lead and tin; pewter, three parts of tin to one of lead; Britannia metal, tin with small quantities of copper and antimony; German silver, three parts of copper with one each of zinc and nickel; and brass, two to five parts of copper with one of zinc, may be mentioned as typical alloys.

Before commencing our investigation we must carefully consider the special points on which our attention shall be focused, to the end that our series of experiments may be properly designed and that the time and labour expended shall be used with the best effect. It may safely be assumed that in order that articles made from the above metallic substances may withstand wear and tear and be suitable in other ways for constant use, the materials of which they are composed should possess the following qualities:

(*a*) They should be light and strong, with a view to convenience in use and as great a measure of permanency as possible.

(*b*) They should be tough, so that rough handling or accidental misuse may not cause ready damage.

(*c*) Their surfaces must not be sufficiently soft to undergo rapid abrasion during cleaning operations, and should preferably be of such a character that careful cleaning preserves the good appearance of articles made from them.

(*d*) For some purposes they require to possess fairly high melting-points.

(*e*) They should not undergo oxidation readily, either at ordinary temperatures or when heated.

(*f*) Water, both cold and hot, should have little or no action upon them.

(*g*) They should resist the attacks of such acids, alkalis, and salts as may be present, or be produced during household operations, or be used in cleansing. Should they be attacked in some measure, the compounds produced should be harmless, or at most but very slightly noxious, to the human subject.

It is hardly feasible to carry out experiments which shall illustrate fully all the above points, and in the course outlined later some of the most important only will be considered. The investigator should obtain samples of as many of the metals mentioned above as convenient, and these should, as far as possible, be of similar character. The best form for general use is that of thin sheets, and most metals are obtainable in this state. For some special purposes small lumps of metal are preferable. These should be as nearly as may be of similar size and shape. The reason for procuring the specimens of the various substances in similar forms may readily be grasped if it be considered that it would obviously be more difficult to obtain a proper comparison of the effects of heat upon iron and tin, if the materials experimented upon were in one case a stout iron poker and in the other a sheet of tin foil. Having procured a supply of suitable samples, the subjoined tests may be performed.

139. The first point claiming attention is the matter of the construction of utensils of convenient weight.

EXPERIMENT 153. Determine the specific gravity of a specimen of each of the metals obtained. For this purpose a small lump of metal will serve better than a thin sheet. The method used should in general be that of Experiment 29, Part I. A study of the values obtained will give a fair idea of the relative weights of vessels made of similar thicknesses of material from the metals tested. This evidence should be considered in conjunction with that gained in the next experiment, which aims at affording an approximate idea of the capacity of each metal for resisting rough or careless use.

EXPERIMENT 154. Place each of the small lumps used in the preceding experiment in turn upon a flat surface of iron or steel. A small anvil is excellent for this purpose, but, failing that, the bottom of a 14 lb. or 28 lb. weight will serve as an efficient substitute. Strike each sample several sharp blows with a hammer, giving each similar treatment in this respect as far as practicable. Note whether the metal is readily indented and also whether it exhibits any tendency to brittleness.

Tabulate your observations in brief form side by side with those of the previous experiment. It will be well if the table be drawn up so as to include not only these results, but also those of the succeeding tests. In this way a clear estimation of the comparative suitabilities of the metals for various purposes may be readily obtained.

140. The influence of polishing materials may be tested by the method of

Experiment 155. Small sheets of the various metals—say 5 cm. square—may be used. Weigh each carefully and then treat each in turn with a scouring medium consisting of silver sand moistened with water, vigorously rubbing each piece for at least 10 minutes. A stiff brush may be used in conjunction with the wet sand. Wipe away all sand and moisture carefully and examine the appearance of the metal. Reweigh and determine the percentage loss of weight, if any, as a result of the scouring.

Repeat the above operations with fresh samples, using (*a*) whiting (finely powdered chalk) rubbed down with water; (*b*) any commercial polishing paste or "liquid polish". In these latter tests use a softer brush or a piece of cotton or woollen fabric instead of the stiff brush. Examine and reweigh after treatment. Unless a fairly delicate balance, sensitive to a difference of weight not greater than 1 mg., be available, the reweighing will probably supply no evidence of appreciable loss of weight, and may be omitted.

141. The following experiment will afford some idea of the behaviour of the different metals when heated to various temperatures.

Experiment 156. Weigh out from one to two grams of each kind of sheet metal at hand. Place each piece in turn upon the inverted lid of a small porcelain crucible, supported upon a pipeclay triangle on a tripod. Arrange the flame of a Bunsen burner at such a height that the tip of the flame just reaches the under-surface of the lid. Heat in this way for five minutes. Note any changes which occur. Next increase the size of the flame a little and allow the heating to continue for a further five minutes. Again increase the size of the flame and reheat with the larger flame. Continue this until the full supply of gas and air is in use and the tip of the inner blue cone of the flame just reaches the under-surface of the lid. Allow the heating with the full power of the Bunsen burner to go on for ten minutes. Then remove the burner and allow the lid and its contents to cool. Examine the metal from time to time while cooling.

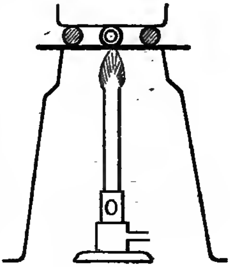

Fig. 81.

Some points which call for special notice during the course of this experiment are as follows:

(*a*) whether the metal has fused or not;

(*b*) if fusion occurs, whether further heating causes any part of the metal to volatilize;

(*c*) whether any sign of chemical action may be observed, *e.g.* whether the appearance of the metal has altered in any way, or its condition been changed, or fumes have been produced, or the weight of the residue differs sensibly from that of the original metal.

The inferences to be drawn from any observations made are left for individual effort, as are also any difficulties met with in carrying out the operations suggested in the case of any particular metal.

*Exercise for Student.*

Suggest reasons for carrying out the heating in some such manner as that described above.

142. The action of water upon each metal requires the performance of a series of separate experiments and, from a comparison of the results obtained, a general statement of the behaviour of the individual metals may be drawn up. In this connection, reference may be made to Experiment 55, Chapter v.

Experiment 157. Treat similar weighed pieces of each metal in the form of foil as follows;

Put a few drops of tap-water on the centre of each piece and allow the foil to remain exposed to the air until the water has entirely evaporated. Repeat the addition of water and slow evaporation at ordinary temperature several times. Examine the metal at frequent intervals and weigh again at the end of the experiment.

Experiment 158. Repeat the procedure of the preceding experiment, using

(*a*) distilled water;

(*b*) tap-water recently boiled for 15 minutes and allowed to cool in a well-filled closed vessel;

(*c*) distilled water similarly boiled and cooled.

Experiment 159. Weigh out samples of each metal—foil preferably—and place them in vessels containing measured volumes of tap-water. Heat the liquid to boiling and continue the heating until two-thirds of the water has boiled away. Fill up the vessels with measured volumes of fresh tap-water and reheat. This filling up and reboiling should be done several times, the total volume of tap-water used being carefully noted. Next remove the metal, rinse it in distilled water, and dry it by gentle pressure between filter-papers. Note any change in its appearance and determine any change in weight by reweighing it.

Make up the residual volume of water to that originally taken by the addition of distilled water, including the water in which the metal was rinsed. Mix the liquids thoroughly. Evaporate six drops of the clear portion of the resulting liquid to dryness on a watch-glass and compare the quantity of residue obtained with that left when six drops of the tap-water are treated in similar fashion.

Dry a filter-paper by placing it in a steam oven for at least 15 minutes. Find the weight of the dried paper. Filter off any sediment that may be contained in the vessel used above through the weighed paper, washing out the last traces of sediment into the filter with distilled water. Preserve the filtrate for further treatment. Dry the filter and its contents in the steam oven and, when cool, weigh. Replace in the oven for 10 minutes, cool, and reweigh. Repeat this treatment until the weight remains constant. Find the weight of the residue on the filter-paper.

Evaporate the filtrate from the last operation to dryness in a weighed porcelain dish. Use a small dish and add the filtrate in instalments if its volume is too great to allow it all to be placed in the dish at the same time. Wash out the vessel containing the filtrate with distilled water and transfer the washings to the dish. Use a small flame towards the end of the evaporation and do not continue the heating after the last traces of water have disappeared. Weigh the dish and its contents when cool. Find the weight of the residue in the dish.

A "blank" or "control" experiment should be performed with tap-water alone, in order to obtain a true view of the nature of the action of the water upon the metals. Boil a quantity of tap-water equivalent in volume to that used above in a similar vessel, adding a similar volume of water to that employed for making good the loss by evaporation. Determine the quantity of sediment and the weight of matter in solution after thus boiling it, using the same method of procedure as that just described.

EXPERIMENT 160. Repeat the treatment outlined in the previous experiment, using distilled water throughout, and checking the observations noted by means of a blank experiment in which distilled water alone is boiled in the vessel used.

143. In order to estimate the nature of the chemical action of the various substances used or produced in cooking, or employed in cleansing, upon metals, a similar series of experiments to those described in the case of water should be carried out with one per cent solutions of each of the substances mentioned in the subjoined experiment. Such solutions will in most cases be much stronger than those actually occurring in practice, but the results will be obtained more readily than would be the case were solutions of lesser concentration employed.

EXPERIMENT 161. Make one per cent solutions of the substances named in the list below by dissolving 10g. of each in distilled water and making the resulting solution up to a total volume of one litre by the addition of a sufficient further quantity of distilled water. Should there be any residue in any case, insoluble in hot distilled water, it may be neglected. Its presence will not affect the *chemical* action, and the clear solution may be used, leaving any sediment undisturbed.

Test the effect of solutions prepared as above upon weighed quantities of each kind of metal foil, the solutions being first used cold, and then hot. Some substances which may be dissolved are

(*a*) acetic acid;
(*b*) oxalic acid;
(*c*) tartaric acid.

(These acids may be considered as representing roughly the organic acids present during the cooking of vegetable substances.)

(*d*) common salt;
(*e*) cane sugar;
(*f*) washing-soda;
(*g*) borax;
(*h*) ordinary hard yellow soap;
(*i*) scouring soap, *e.g.* Sapolio;
(*k*) washing-powder.

EXPERIMENT 162. Further tests may be made in similar fashion to those of the last experiment, using two or more of the liquids there employed in conjunction with one another. As examples, try the effect of

(*a*) acetic acid and common salt,
(*b*) tartaric acid and cane sugar

upon each metal.

144. It is evidently not advisable for the individual student to test the effect upon the human economy

of the various bodies that may be produced during the above experiment both on account of the danger involved and also because some of the harmful products are cumulative in their action, *i.e.* the injurious effect of each successive small amount ingested is superadded to that of its predecessors, so that no serious result is produced until the quantity absorbed has reached a sufficiently large total to bring about troublesome symptoms. In general, it may be noted that the salts of copper, silver, and lead are distinctly harmful, those of zinc less so, while those of tin and iron have no appreciable harmful effect in such small doses as would occur in ordinary practice in household affairs.

145. Should the time at the disposal of the experimenter be somewhat limited, it will be better to choose two or three suitable metals for each experiment suggested above and to carry out a systematic investigation with these, rather than to attempt all the experiments described with all the metals. In many cases, comparable results, approximating to those noted in actual household practice, cannot be obtained unless the tests are sufficiently prolonged.

On the other hand, should time permit, a further series of tests, of somewhat similar character to those already done, may be performed, using such substances as tinned iron or tin plate—made by dipping thin steel sheets into molten tin; "galvanized" iron—similarly produced, zinc being substituted for tin; electroplate—obtained by electrical action, a thin coherent film of a metal such as gold, silver, or nickel, being deposited upon an article made of a cheaper metal, such as brass or copper; earthenware; glass; and enamelled iron—iron covered with a thin layer of glass to which a white substance, such as tin dioxide or barium sulphate, or a suitable coloured medium, has been added. Further, the actual experiments as outlined may be repeated in modified forms, the modifications introduced being those which the experience gained has suggested to the observer, while others of like character may be readily devised, whereby some special observation may be more prominently exhibited.

146. Another matter deserving of attention, upon which some simple experimental work may well be carried out, is the investigation of the nature of the action of flame gases upon various metallic and other substances. Both Bunsen and ordinary luminous gas flames may be used and comparisons made of the corrosive effect of each upon the different bodies used. The arrangement of a suitable series of experiments under this head is left as a practical exercise for the student desirous of conducting a simple form of research without the aid of teacher or text-book.

## QUESTIONS

1. Which would be the most suitable metal for the construction of a cold-water cistern—lead, iron, or galvanised iron? Why? Would your choice be affected in any way by the nature of the water supply?

2. Would you alter your choice as in Question 1 if the cistern were required for hot water? Give your reasons.

3. Copper kettles are frequently coated internally with a layer of tin. What is the object of this treatment?

4. The joints of kettles are usually sealed by means of soldering. Why does not the solder melt when water is boiled in the kettle?

5. Suggest some objections to the use of galvanised iron as a material for kettles and saucepans.

6. Metals are in general good conductors of heat. In what ways is this property of service in household affairs?

7. For what purposes would you consider enamelled ware especially suitable? Why?

8. Why are vessels of porcelain so little used for cooking utensils? In what respects do you consider that their more extended use would be advantageous?

9. Water-pipes are sometimes made of lead. Why is this metal distinctly unsuitable for use with certain kinds of water?

10. What do you consider to be the value of galvanising iron as shown by the results of any experiments you have performed with this material?

11. Lead is frequently used as a roofing material. To what qualities does it owe its value for this purpose? Mention any disadvantages which occur to you.

12. Discuss the relative values of iron and aluminium as suitable substances for the manufacture of saucepans and frying-pans.

# EXAMINATION QUESTIONS

1. What gases may be found dissolved in natural waters? Of what service are some of these to animal and vegetable life?

2. Describe the manner in which a closed combustion stove heats a room. Give the advantages and disadvantages of a stove compared with an open fire.

3. Give a description of a simple system of hot-water heating, showing clearly the path taken by the water, and giving reasons for its passage from one part of the system to another.

4. Describe a method of demonstrating (*a*) the boiling-point, (*b*) the freezing-point, of water. Under what conditions is the boiling-point seen to vary from the normal?

5. Give reasons for the following practices: (*a*) surrounding ice with loosely woven woollen cloth in hot weather; (*b*) placing the boiler of a hot-water system in the basement of a building; (*c*) constructing the back and sides of an open grate of fire-brick.

6. In a room with closed doors and windows, and no fire, but lighted by gas, what differences of temperature would you expect to find by means of a thermometer placed in different parts of the room, and why?

7. Show clearly how three methods of transmission of heat are concerned in the operation of heating water in a kettle over a clear kitchen fire. How would the time required to raise the temperature of the water to boiling-point be affected by the presence of soot on the bottom of the kettle?

8. Carefully describe a method of combining the heating and ventilation of a house or other building. What measures should be taken to ensure the sufficiency and purity of the air supply?

9. Describe a common thermometer and state how you would proceed to test its accuracy.

10. In what ways may the air of enclosed spaces be rendered unsuitable for breathing? What are the main objects to be kept in view in arranging for the proper air-supply of such a space?

11. Describe with diagrams the different ways in which a building may be ventilated.

12. Explain the construction of a Thermos flask. Why is this pattern of flask of service both for keeping hot liquids warm and cold liquids cool?

13. A house is to be heated by open fires. Explain with diagrams the kind of grate you recommend for the living-rooms, and the arrangement of the fire-places, chimneys, and air-inlets in the rooms which you think best to ensure efficient heating with economy of fuel and good ventilation.

14. Describe an experiment to show that air is a bad conductor of heat. How has this fact been used in the production of warm clothing materials? What is the principle of the Thermos flask?

15. Compare the construction of a modern open grate with that of a modern gas stove. Which do you consider the more hygienic form of heating apparatus? Why?

16. Describe any form of barometer with which you are acquainted. What is measured by means of this instrument? How would its readings be affected by taking it to the top of a mountain and also by carrying it down a deep mine?

17. Why is it necessary that the air of a living-room shall be frequently changed? Name the chief agencies by which the required change is usually effected, and describe a simple system of ventilation, showing clearly the parts played in it by the agencies you mention.

18. State clearly the tests you would apply to a sample of water in order to discover its suitability or otherwise for laundry use.

19. Describe a method of preparing suitable drinking-water when sea-water only is available.

20. How may it be shown that water is a compound of two elements? Give the names of these elements and state two distinctive properties of each.

21. Show how a supply of pure water might be obtained from a muddy pond. Why is water of doubtful character rendered less harmful by prolonged boiling?

22. Name the more important substances which are found dissolved in water from different natural sources. How do any of these substances affect its action on lead water-pipes? What other factors influence the action of water on lead pipes?

23. What is meant by the terms *hard* and *soft* as applied to water? What waters are likely to be hard, and why are they unsuitable for domestic purposes? How can they be rendered suitable for use?

24. State the substances that drinking-water may contain and how their presence may be explained. How would you detect the presence of organic matter in water?

25. What precautions should be taken in the storage of water in a house?

26. Sketch the apparatus you would employ to obtain pure water from sea-water. In what respects would such water differ from ordinary drinking-water, and how could it be made more palatable?

27. Water is supplied to a house by a mountain stream; what measures would you take to ensure that the supply is constant and pure?

28. What are the characteristics of good drinking-water? From what sources may such water be obtained, and how may it become impure during storage in cisterns?

29. How is coke made, and of what does it chiefly consist? In what respects does a coke fire differ from a coal fire and how is the difference explained? What does coal ash consist of?

30. Describe the principal characteristics of the two gases, carbon dioxide and monoxide, and how each gas is recognised when pure. What important difference is to be noted in the effect of these gases on men and animals?

31. If a colourless liquid were given to you, by what tests could you prove it to be water?

32. Give an account of what is seen after a fresh supply of coal has been placed on a glowing fire in an ordinary grate. Why are common grates said to be wasteful in action?

33. Describe clearly the experiments you would perform in order to find out whether a given water-supply was temporarily hard or permanently hard, or whether both kinds of hardness were present.

34. Describe the construction of a Welsbach burner. Of what service is the perforated gauze which covers the opening of such a burner?

35. What substances could you prepare, if supplied with the following: sulphuric acid, salt, and water? Describe fully the preparation of any one substance you mention.

36. Define the terms "acid" and "alkali." Write an account of any experiments you have performed in illustration of the properties of these substances.

37. Describe experiments which illustrate the properties of *either* ammonia *or* washing-soda. Show how from these experiments you can infer the special cases in which each substance is likely to be (*a*) useful, (*b*) harmful, if added to water and used for washing. How far does your practical experience bear out these inferences? Give definite examples of cases where you have used ammonia or soda and describe the results.

38. What properties are common to acids? Show that these are exhibited by the volatile product obtained on heating saltpetre with sulphuric acid.

39. Salt obtained from a salt mine may be found mixed with earthy matter. Describe carefully the various operations necessary for the separation of pure dry salt from the impure material.

40. By what properties would you distinguish acids from alkalis and from salts? How would you classify borax, washing-soda, oil of vitriol, lime?

41. Describe carefully the changes which occur when (*a*) steam is passed over red hot iron nails, (*b*) air is passed over red hot copper. From which two of the substances obtained in these experiments could water be reproduced, and how?

42. Draw a diagram of a Bunsen burner and explain its action.

43. Give the chemical names of washing-soda, spirit of salt, and common salt. How would you obtain a sample of the last-named from the other two?

44. Name the chief substances used as disinfectants. For what special purposes is each suitable? Describe fully the method of using any one of those you mention.

45. Mention three solvents which are of service in the household and describe the method of using each.

46. How would you remove (*a*) iron-mould from a pocket-handkerchief, (*b*) mildew from a towel, (*c*) ink stains from a white cotton frock?

47. How is common hard soap made? Explain the effect of adding some vinegar or other acid to a solution of soap.

48. What happens when fat is boiled with caustic soda, and when an acid is added to the product? What is the cause of the curd produced when soap is used with hard water?

49. How is ordinary hard soap made? What alteration of the process is necessary for the production of soft soap?

50. How is soap made? Suggest an explanation of its value as a cleansing agent and describe any experimental work you have done which bears out your explanation.

51. What tests would you employ in order to determine whether a certain fabric, supposed to be linen, contained cotton?

52. Why is wool usually preferred to cotton as a material for underwear? How would you discover whether a given material was a pure woollen fabric or a mixture of wool and cotton?

53. What substances are produced from sugar by fermentation with yeast, and how can these be separated and identified?

54. How can starch be obtained from flour, and how would you show that substances obtained by a similar process from rice and potatoes are probably identical in composition with wheat starch?

55. A white powder is suspected to be either starch or sugar. What tests would be necessary to establish its identity?

56. How is the fermentation produced by lower organisms made use of in the preparation of human food?

57. How would you prove the presence of carbon and hydrogen in such a substance as sugar, and of carbon, hydrogen, and nitrogen in cheese?

58. To what is the putrefaction of meat due? By what experiments could you demonstrate the truth of your answer? What different means are used to preserve meat and fish for transport? Show why they are effective.

59. Why do beer and wine become sour when exposed to the air? Mention any other changes with which you are acquainted which are effected by similar agencies.

60. How would you separate a mixture of cane-sugar and starch? By what tests would you recognise the presence of each of these substances in solution?

61. How do starch, glucose, and alcohol differ in composition? Outline the methods you would use in order to transform starch into glucose and the latter substance into alcohol.

62. Suggest a method of obtaining a sample of alcohol from starch. How would you know whether the liquid you obtained was alcohol or not?

63. For what substances is Fehling's solution of value as a test? Describe clearly the method of carrying out a test with this liquid.

64. Why does food exposed to the air usually become unfit for consumption after a certain time? Mention three methods by which foods may be preserved and state clearly the reason for preservation in each case.

65. Give the composition of any form of baking-powder with which you are acquainted. What is the function of each of its ingredients?

66. The average specific gravity of milk is 1·032. How would you proceed in order to discover whether a sample of milk was above or below the average in this respect? What inferences would you draw as to the character of the milk if your result proved (*a*) high, (*b*) low?

67. Explain fully how you would determine the density of a sample of milk. Of what value is this determination as affording evidence of the genuine character of the sample?

68. Describe a simple form of lactometer and explain how it is used. How far is a lactometer a sufficient guide in determining the purity of milk?

69. What experiments would be necessary to demonstrate the presence in ordinary beer of (*a*) carbon dioxide, (*b*) alcohol, (*c*) sugar?

70. Enumerate all the carbohydrates that you know of and mention an article of food in which each is found. Mention the changes that carbohydrates undergo in the alimentary canal.

71. What are the important food-constituents of bread? What changes are effected in it (*a*) in the mouth, (*b*) in the stomach?

72. Describe exactly how you would (*a*) make bread, (*b*) boil a leg of mutton, (*c*) make a rice pudding. Explain as far as you can the reason for your actions, and discuss how the digestibility of the substances concerned is influenced by cooking.

73. Suggest a series of simple experiments which might be carried out in order to find out whether tap-water, weak brine, and weak solution of washing-soda had any effect upon aluminium.

## ANSWERS TO QUESTIONS INVOLVING CALCULATIONS

### CHAPTER IV. Page 104.

8. 7*s*. 9*d*.
10. 125 hours lighting by gas costs 3*s*. 4*d*.; by electricity, 3*s*. 9*d*.

### CHAPTER VIII. Page 190.

6. 12 lb. 7 oz. (to nearest ounce); 12·45 pints.

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